The Life-History

of

The Salmon

By

J. ARTHUR HUTTON

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THE LIFE-HISTORY
OF
THE SALMON

BY

J. ARTHUR HUTTON

WITH AN INTRODUCTION BY PROF. J. ARTHUR THOMSON

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INTRODUCTION.

By Prof. J. ARTHUR THOMSON, M.A., LL.D.

The Aberdeen Natural History and Antiquarian Society has had from time to time the benefit of lectures from distinguished visitors, and one of these, which formed the basis of this volume, was delivered on the 25th of May, 1923, by Mr. J. Arthur Hutton, of Alderley Edge, on the " Life History of the Salmon." This masterly lecture, which expressed the results of many years of careful study of salmon and their scales, excited great interest, and many who heard it expressed the wish that it should be published so that they could study it at leisure. The secretary of the society, Mr. Robert M. Clark, approached Mr. Hutton on the subject, and was met with kind acquiescence. For this, as well as for the delivery of the lecture, the society is very grateful to Mr. Hutton. And not only has he prepared the lecture for the press, but he has generously supplied the interesting illustrations.

When a man speaks on a subject with which he is intimately familiar, and for which he has a natural enthusiasm, the result is always worth having and diffusing; and the Executive Committee of the Society felt confident that many of those interested in angling and in freshwater fishes would welcome Mr. Hutton's accurate account of the life-history of the salmon. But the Committee hopes that it will appeal also to the wide circle of those who find a delight in the Natural History of the country. The salmon is a familiar animal, and everyone should be acquainted with its life-story, which is not without a romantic touch. Thus the Society has reason to congratulate itself on being able to add Mr. Hutton's contribution to the very valuable series already published, of which the Society may well be proud. These are procurable on application to the Secretary.

There are many problems still to be solved in connection with the salmon, but its life-history is known with more precision than that of any other fish, unless it be the eel's. For this precision we have to thank, in great part, the method of scale-reading, for that has made it possible to tell with certainty how old the fish is, how often it has gone down to the sea, how many times it has spawned, and so on. Advantage is taken of a bodily registration, which is characteristic of living creatures in general, though it is rarely so legible as in the salmon's scales. The discontinuous character of the growth of the scale is like that seen in the rings of a sawn tree, where the difference between the spring-growth of wood and the late summer-growth makes counting easy. Similar rings are familiar in some of the bones of fishes and in the ear-stones or otoliths, but those of the scales are clearest. Lines of growth are also obvious on the horny scales of a tortoise, or on the shell of a scallop, but only in a few cases has it been determined how many of the more or less parallel lines are laid down in a year or season. In all cases we have to do with the ripple-marks of growth, and the general biological fact is that a deep intrinsic tendency to rhythm in the vital processes of the body has been punctuated in relation to external periodicities and changes of habitat. It is more than fanciful to say that the salmon keeps its diary on its scales, and it is a great pleasure to follow Mr. Hutton in deciphering the story.

The life of an animal is often a see-saw between nutrition and reproduction, and the alternation is very marked in the case of the salmon. There is the nutritive period in the sea, where the fish feed on herring, mackerel, sand-eels, some crustaceans, and the like, accumulating great stores of potential energy ; and there is the period in fresh water, which is for the adults a time of fasting, more or less strictly observed. But this time of fasting is the time of pairing and multiplying. Here we have an instance of the swing of the vital pendulum—" a time to tear down and a time to build up ; a time to preserve and a time to throw away ; a time to embrace and a time to refrain from embracing." Whether we think of foliage and flowering, or of the voracious caterpillar and the ascetic butterfly, it is the same fundamental antithesis—" a time to seek and a time to lose," an alternation of relatively preponderant anabolism and relatively predominant katabolism. But is there any illustration more dramatic than the contrast between the maiden fish and the kelt ?

Mr. Hutton has a very attractive theme, and he has treated it sympathetically. There is something very picturesque in a well-defined life-curve—the gradual ascent from the *vita minima* of the embryo, the passage from adolescence to maturity, the crest of the wave and the prime of life, and then the down-grade. " And so, from hour to hour, we ripe and ripe, And then, from hour to hour, we rot and rot, And thereby hangs a tale." But in the case of the salmon, if the kelts " mend " and do not fall victim to parasites or enemies in the time of their debility, they may live to a good age, perhaps eight years, and then die young! For most fishes come to a more or less violent end before they show any traces of more than senescence. We do not know that salmon ever show senility.

What a remarkable story it is that Mr. Hutton tells, and how well he tells it! Late in the year the liberation of the eggs in the furrow scooped by the female among the gravel, and the covering of them with pebbles; their more or less fortuitous fertilisation by the attendant male; the long drawn-out embryonic development during the cold months, for cell-divisions are slow when the temperature is low; the hatching of the eggs after three months or so and the emergence of the alevins, which are not a little handicapped by their legacy of yolk. They cannot swim rightly because of the yolk-sac, and they hide among the loose stones, absorbing their nutritive reserves for a month or even two months. When the store is exhausted they have changed into inch-long fry able to fend for themselves. By the end of the year the survivors have become parr, perhaps four inches long, hungry for insect larvæ. When two and a quarter years have passed the nine or eleven finger marks on the side of the parr become masked by a silvery sea-jacket, and there is a change of constitution expressing itself in restlessness. The parr have changed into smolts, about six inches long, which hear the call of the sea--in some way that we do not understand. In the sea, with a change of diet, the smolts become grilse, but the intermediate stages are little known. A grilse is usually about three and a half years old, and it may enter the river during the summer to spawn in the fall of the year. Mr. Hutton tells us how the scale of the grilse shows, for its sea-life, a summer zone, a winter band, and the beginning of a summer zone; and there are other features which enable the experienced angler at once to say, "That is a grilse." It seems rather difficult to put into words what the defining characters are, but the grilse has not the shape of the salmon, being more slender towards the tail, and the teeth of the upper jaw are different. Some fish pass through their grilse stage without ascending the rivers to spawn; indeed, they may remain in the sea till they are five or six years old.

The life-history, as Mr. Hutton tells it, raises many thoughts. There is the severity of Nature's sifting: "So careful of the type she seems, so careless of the single life." How many of the eggs are swept down-stream, how many are left unfertilised. Eels seek out the alevins, trout gulp down the fry, pike devour the parr, coal-fish wait for the smolts at the mouth of the river, seals harry the salmon in the sea, the otter finds the kelt an easy prey. So when we watch a fine salmon being landed by the completely happy angler, we know we are witnesses of the end of a long lifetime of gauntlet-running. The fish has done much surviving in its day, and though it has never been what one would call intellectual, it has been no fool in the art of life.

But while the life-history can now be well described, as Mr. Hutton's lecture shows, we are far from an understanding of the course of events. We are only beginning to study the physiology of what happens. It will be necessary to work out the constitutional changes that mark the transition from parr to smolt, and those that prompt the salmon to leave the spread tables of the sea and make the journey against the stream—all on an empty stomach. "Hunger is eaten up of love," but what does that spell in physiological language?

The word salmon means "leaper," and the climax of the life seems to us to be the ascent of the rapids. It is a notable gymnastic feat to shoot a heavy body clean out of the water, and that is what the leaping salmon does. It can in one spring clear a waterfall the height of a tall man, and this is not the limit. In what ratio the increase of weight reduces the jumping powers, we do not know ; but it is to be remembered—who can forget ?—that the bulk of the body is sheer muscle, a multitude of mysterious motor engines. Large masses of water are thrust out from side to side alternately, and considerable velocity may be attained against the stream before the actual spring is taken. The salmon surmounting a fall is one of the finest emblems of that deep characteristic of life which we venture to call insurgence.

Mr. Hutton wisely refrains from committing himself to an answer to the difficult question : Is the salmon originally a freshwater fish that has taken to colonising and exploiting the sea, just as the eel is a deep sea fish that has taken to exploring the rivers ? ; or is the salmon originally a marine fish that has learned to seek spawning-safety in the rivers, and is even now learning to do it better and better ? We must follow Mr. Hutton's caution, but we are sure of this, that whichever answer is given, we must hold to the idea that the salmon is a historic being—a personality of a piscine grade—whose present behaviour is dominated by a past that never dies.

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SUMMARY OF THE STAGES IN THE LIFE OF THE SALMON.

1. The egg-cells or ova, produced in the " roe " or ovaries, are liberated by the female fish and fertilised externally by sperm-cells or spermatozoa from the male. The seminal fluid, produced in the testes of the male fish, is known as " milt."

2. The fertilised egg-cell develops into an embryo, and the word embryo is used as long as the developing fish is still within the egg-membrane. Embryonic life ends with hatching.

3. Alevins are the newly hatched young fishes, still weighed down by the large yolk-sac, which furnishes food for a month or two.

4. When the yolk-sac has been absorbed, and the young fishes are about an inch long, they are called " fry." But the term is often used to include the alevin-stage.

5. Parr are young salmon showing seven to eleven large bluish marks, oblong or oval in shape, along each side. This stage continues till the young fishes are about two and a quarter years of age. A common size at the end of the parr stage is about 6 inches.

6. Smolts are young fish about to go down to the sea, or already on their way. The parr markings have been obscured by a silvery jacket.

7. Grilse are usually fish that went down to the sea as smolts the previous season, and are now between three and three and a half years old. They have the adult coloration, but have some juvenile features. For the marine period their scales show a summer-zone, a winter-band, and the beginning of another summer-zone. They may ascend the rivers to spawn as grilse, or they may pass through the grilse stage in the sea and continue to live there for more than a year. Some fish do not enter fresh water till they are four to six years old.

8. " Salmon " are fish beyond the grilse stage, whether they have spawned or not; and here we must recognise various useful names, like " maiden fish " for those that have not spawned, " unclean fish " for those that are nearly ready to spawn or have recently spawned, and " kelts " for those that are " spent " after spawning.

THE LIFE-HISTORY OF THE SALMON.

BY J. ARTHUR HUTTON.

OUR politicians are very fond of talking about the development of the resources of the Empire, but, as is usual with talk of this kind, all the suggestions made are very vague and, as a rule, refer only to the Dominions and Colonies. These gentlemen seem to forget that Great Britain is one of the most important parts of the Empire, and they entirely ignore the fact that there are resources in this country well worth developing. After all, charity begins at home.

I wish to draw your attention to a very important national asset which lies at our very door-step, and one which, I am sorry to say, is anything but developed. I refer to our Salmon and Freshwater Fisheries. In this treatise I propose to deal with the salmon fisheries only.

Unfortunately there is an enormous amount of prejudice and ignorance about this question. If one ventures to suggest to one of our legislators that our salmon fisheries are a valuable asset and well worth developing, he will at once reply :

" Oh, what is the good of talking about salmon ? Salmon fishing is merely the amusement of the idle rich, and, after all, the fish itself is only a luxury not worth consideration."

Salmon Not a Luxury.

Now salmon is not a luxury. It is a very valuable form of food, and even at present prices is comparatively cheap as compared with many other kinds of food, which are bought by people who are by no means well-to-do. I must confess that I find it very difficult to persuade people that this is so, but I will give you a few figures, which fully confirm the above statement. For example, compare salmon with cod. There is very little waste in salmon, and the skin and bones amount to 23 per cent. only, or barely one-quarter of the total weight of the fish. With cod, on the other hand, the wastage is 49 per cent., or very nearly half of the fish. Then, again, the flesh of salmon is extremely rich and nutritious. One pound of salmon contains over 700 food calories as compared with 166 in one pound of cod. What it comes to is this, that salmon at 4s. per pound is as cheap a form of food as cod at 1s. per pound. Or, to put it in another way, a quarter of a pound of salmon costing 1s. will give more food than one pound of cod also costing 1s. It equally follows that when the price of salmon falls below 4s. it is a really cheap form of food.

Salmon Fishing an Important Industry.

Rod-fishing for salmon is only a small part of the business. Netting is the main thing, and for every 100 salmon caught with rod and line over 1000 are caught with nets or traps. In England and Wales alone considerably over 3000 men get their living by netting for salmon, and of course in Scotland a far larger number are employed. It should also not be forgotten that the so-called "idle rich" find employment for a large number of people as keepers, gillies, servants, etc., and also spend a good deal of money locally when they "go a-fishing." If there were no rod-fishing in this country a large amount of this money would instead be spent in Norway, Canada, Newfoundland, or elsewhere. I must also draw your attention to the fact that heavy rates are levied on the annual value of salmon fisheries, and, if these ceased to exist, farmers and others would have to pay extra rates to make up the deficiency. The Chancellor of the Exchequer also obtains a considerable amount of money from the income tax paid on the value of these fisheries. It must also be remembered that, at any rate in England and Wales, the rod-fishers provide the largest part of the money spent in the maintenance and protection of our fisheries, which therefore depend on the continuance of the rod-fishing.

Netting is, however, the main part of the business ; but let me impress on you one most important fact—in the long run the interests of rods and nets are absolutely identical. If, owing to over-fishing, the breeding stock becomes depleted, both will suffer alike. On the other hand, if a river improves and the rods make good catches, the netsmen will do equally well, with, however, this difference—that their share of the harvest will be ten times that of the rods. But both depend on one factor—*that a sufficient stock of parent fish are left to breed each year.*

ADVANTAGES OF FISH FOOD.

There is one great advantage of fish as compared with other forms of food. Practically the only cost we incur is that of catching them. If we want to produce, say, meat or corn in this country, we have to provide the land, the machinery, the implements, and the cost of labour. Or, if we want to import food, we have to spend a lot of money in manufacturing exports to pay for it.

In the case of fish caught in British waters, we require neither land, nor machinery, nor labour to fatten and rear the stock. Nature does all that part of the work for us. She hatches out the fish, she nurses and rears them during their early life, and then she fattens them up for the market. Afterwards all we have got to do is to go and catch them. She, however, makes one very important condition—*we must not kill the goose that lays the golden eggs.* We must not ruthlessly destroy every salmon which returns to our rivers. We must leave a sufficient stock of parent fish every year to provide the supply for future harvests.

THE IMPORTANCE OF BRITISH SALMON FISHERIES.

I should also like to point out to some of our ignorant legislators that, even in their present neglected state, our salmon fisheries are of considerable economic importance. Most people think that Norway is *the* country for salmon. It may surprise you to learn that Great Britain and Ireland produce more salmon than all the rest of Europe put together. Before the war it was estimated that Europe produced annually about 3,000,000 pounds weight of salmon. There was over 3,500,000 pounds delivered at Billingsgate Market alone, and there are several other large distributing markets in this country —for example, Aberdeen. The total annual production of salmon in Great Britain and Ireland has been estimated at 6000 tons, or, say, 13,000,000 pounds in weight. Putting the average price at 2s. 6d. per pound, this gives a value of over £1,500,000—a by no means unimportant figure.

FUTURE POSSIBILITIES.

Nature has been especially bountiful to this country. We have the best spawning and rearing grounds in the world for Atlantic salmon, and if our fisheries were properly managed, they could produce a very much larger quantity of valuable and nutritious food. Our salmon fisheries are a great national asset, but I am sorry to say that, in the past, they have been grossly neglected and disgracefully managed. I have given much attention and study to this subject, and I have no hesitation in saying that if they were properly managed the annual harvest could be very largely increased; it certainly could be doubled, and possibly might be trebled, or even more.

MR. H. W. JOHNSTON'S DISCOVERY.

I propose now to give you an account of the life-history of the salmon. There has been a very large amount of literature published on the question, and there has been more legislation about salmon than all the rest of the fishes put together. Most of our laws relating to salmon are based on ignorance and stupidity, and this applies to a good deal of legislation in this country. Up to twenty years ago we really knew very little about salmon, and we were more or less groping in the dark. Therefore all who are interested in the economic development of our salmon fisheries owe the greatest debt of gratitude to Scotland for the wonderful discovery that the life-history of every salmon was indelibly written on practically every one of its scales. By examining a single scale from any fish one can ascertain how long it stopped in the river, when it migrated to the sea, how long it stopped there, and how often it spawned. On October 24th, 1904, Mr. H. W. Johnston wrote a letter to the "Field" giving a short account of his investigations. Since that date a large amount of literature has been published on the subject, and the Scale Theory, as first discovered by Mr. Johnston, has now been proved beyond dispute.

SALMON SCALES.

The fry, when first hatched, have no scales, but these commence to grow at a very early stage of life. Except to replace lost scales, no new ones are acquired. Consequently, as the fish increases in length and girth, the scales must increase in size to cover its larger surface. The scales grow by the addition of rings around the circumference, in something the same manner as rings are formed on a tree. There is, however, this difference—that a varying number of rings are added every year. The question naturally arises—how then can one ascertain the age? Certainly not by counting the number of the rings. This is only waste of time, as the number will not be the same on each of the scales taken from any individual fish.

SUMMER-ZONES AND WINTER-BANDS.

One does not require a microscope to examine the scales. A small pocket magnifying glass is quite sufficient, and it is better not to use too high a power. A magnification of ten to twenty diameters is in most cases quite sufficient. All one has to do is to clean the scale with a pocket handkerchief or with one's fingers and to put it on a piece of glass, and then examine it with a magnifying glass.* On examining the scale one will find that the rings are divided into alternate series of wide open and narrower rings, which latter give the effect of darker bands. The wide rings are formed during the summer, when the feeding is good, and the narrower rings on the approach of winter, when there is less feeding or possibly none at all. (Plate I.)

Therefore, by counting the number of summer-zones and winter-bands one can ascertain the age of any salmon with absolute accuracy up to a certain period of its life. The river-life is sometimes rather difficult, but I can give the investigator a hint which may be helpful. As a rule, the rings formed during the first year of life are complete, that is to say, they are continuous round the whole of the scale. In subsequent years they are generally incomplete, and are non-existent on the exposed or posterior portion of the scale—that is the part which is towards the tail. As a rule, the sea-feeding is quite clear, but like everything else, it requires experience to be able to arrive at sound conclusions. Spawning, which I will deal with later, introduces further complications, but I can assure you that with a little practice it is by no means difficult to ascertain the age of any salmon one may catch, even if it be only from the fishmonger's slab.

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* Messrs. Ross, Ltd., London, and Messrs. Casartelli & Son, Manchester, supply pocket glasses for the purpose.

I think you will agree that it was a wonderful discovery which has thus enabled us, by the examination of a single scale, to find out how long any salmon has lived, and what has happened to it during its life. Thanks to Mr. Johnston, we now know that on practically every scale the life-history of every salmon is clearly written—for those who can read. I should, however, give one further hint—take plenty of scales, say at least a dozen, for it frequently happens that some of the scales are imperfect.

Arrangement of the Scales.

The true skin of the salmon lies underneath the scales, and the latter form an armour to protect the fish. Each scale is embedded in a skin pocket, and these pockets are arranged in rows, which slope upwards, and downwards, from the medial line towards the tail. The scales overlap one another like the tiles on the roof of a house, and one only sees the exposed portion of each scale. The other part, nearest the head, is covered by the adjacent scales. The anterior portion of the scale, that is the part nearest the head, is embedded in the scale-pocket, but the scale has a slight outward slope, so that the part nearest the tail (the posterior portion) is exposed and " free," that is to say, that is does not adhere to the skin. The rings on the exposed portion are only partially formed, and it is on the anterior portion where we find the rings which we want to examine. These rings are bony ridges, which project from the outer surface of the scales, and they can easily be felt with the point of a needle. The under portion of the scales is of a more fibrous nature, and thickens with age. The one main point is that these ridges are permanent and never change, and consequently provide us with an indelible record of the life of the fish.

Colour of the Fish.

The scales themselves are semi-transparent, but each scale is covered with a thin skin or mucous membrane. Colour particles are deposited in this thin skin, and the beautiful pearly silver of the salmon is due to these tiny particles. This is easily proved by removing a scale from a salmon and by pulling it through one's fingers. The silvery particles are left on one's fingers, and it will then be seen that the scale is transparent and has no colour. As the season advances salmon get darker in colour, and it will be found that the scales are less " free," and adhere more closely to the true skin, and they gradually become more difficult to remove. This is especially the case with cock-fish, and just before spawning it requires almost a surgical operation to detach them. The mucous membrane or thin skin becomes harder and firmer, and the scales are less visible. This explains why it is sometimes supposed that salmon shed their scales. Cock-fish also get more or less red as the spawning season approaches. This is due to a *pigmentary* deposit. After spawning, the Kelt—or spent-fish—slowly recovers, and eventually the colour of the fish gradually changes, and they again become bright and silvery. There is, however, something " meretricious " about the colouring of the kelt. An early-run spring-fish has a bright pearly look about it, whereas the kelt is distinctly " whitish " in appearance. As a friend of mine aptly described it, " it is the difference between the brightness of tin and silver."

Variations in Different Rivers.

I propose now to go through the various stages of the life of the salmon, commencing with their first return from the sea to the river to spawn. Let me say at once that most of the following is based on investigations in the Wye. There is no doubt that there is a good deal of variation in habit in different rivers.

For instance, the two main classes in the Wye are the large Spring and the Small Summer-fish, whereas I understand that in the Dee the principal run consists almost entirely of Small Spring-fish. Some rivers are early, other rivers are late. Some rivers have large fish, and in others salmon are usually small. Each river seems to have its own local type, but what applies to the Wye will, I think, generally speaking, be a guide to what one may expect in other rivers.

Different "Runs" of Fish.

Given suitable running water, salmon may run up the Wye at any time of the year from January to December. Salmon are roughly classified into two main types :—

Spring-fish, which return to the river in January to May ; and

Summer- or Autumn-fish, which run in the later months.

These two types can again be sub-divided into Small and Large Spring- or Summer-fish.

We have also two other classes—Grilse, which are the adolescent as compared with the fully matured fish ; and also the largest type of spring salmon, which have remained at least four years in the sea without returning to the river to spawn.

The remarkable fact is that no matter when the fish return to the river, all these various classes will spawn in the following winter and within a comparatively short time. I have seen fish "cutting" in September, and I have also seen fish spawning in February. I have also heard of belated spawners in March, and even later. However, in the Wye the great majority of the salmon spawn in November. It is worth noting that during the last fifteen years the main spawning season has become quite a month earlier. Formerly December was the great spawning time.

The Migratory Instinct.

The migratory instinct in salmon is one of the marvellous facts in Nature. The eggs must be deposited in the river, for salt water is fatal to them. The Fry hatch out in the spring, and their growth in freshwater is comparatively slow. In the Wye the Parr, as they are then called, will at the end of the second year's growth run from about 4 to 6 inches long. When they are sufficiently matured Nature tells them that they must be off to the sea. This period will vary in different rivers. In the Wye some will migrate when they are only twelve months old, but the majority go off to the sea as Smolts when they have completed their second year, and some few will remain in the river for three years. This Smolt-migration always takes place in the spring—say from March to the beginning of June—no matter whether they have been living for one or two or more years in fresh water.

Then, again, when they reach the sea, they do not all remain there feeding for the same extent of time. Nature has her rules, and she will compel some to return to the river as grilse to reproduce their species after spending a little more than a year feeding in salt water. Others are allowed to remain there for two years or more, and this may be extended to three or four or even five years. There can, however, be no question that, when she gives her orders, the salmon have to obey. To put it into words, " You have had a glorious time gorging and guzzling in the sea. It's now time for you to do a bit of work. Off you go back to your river and reproduce your species."

One of the extraordinary facts, which has been proved by marking fish, is the wonderful " homing-instinct " implanted by Nature, by which the fish are guided back to their own rivers. With a few exceptions, which are probably due to mistake, salmon always return to their own river. In 1905, 6500 smolts were " marked " in the Tay as they were migrating to the sea. A good many of these were recaptured in this river when returning to spawn, but not a single one was reported from any other river. I do not think that there is now any doubt that, guided by this wonderful homing-instinct, salmon almost invariably return to their own rivers. I would go even further, for I believe they endeavour to get back to the very tributary in which they were born.

Spawning Journey.

This migratory instinct implanted by Nature must be most extraordinarily strong. We don't know how far out into " the blue " they go, but they certainly do not hang about the coast, as is the case with sea-trout. The capture of sea-trout in estuaries and along the coast is comparatively common at all times of the year, and in all the various stages of life. It is a very rare thing for a salmon to be caught in the intermediate condition between the Smolt and Grilse stages. I believe that smolts, after reaching salt water, very soon make for the open sea, and that afterwards they seldom approach the coast except when they are returning to their own river to spawn.

Anyhow, however far out to sea they go, when the spawning instinct seizes them, they have to make for the coast and find their river, and undertake the most serious task of their lives. This spawning journey is a most dangerous and arduous one, and they have many enemies and dangers to face. They may have miles of nets to pass, and sometimes the entrance to the river is all but blocked. The wonder to me is that there are any salmon left to carry on the race. If that messenger were to come down from Mars, he might well believe that our main object was to utterly destroy the species.

Then, again, when they approach the coast, they have in many cases to run the gauntlet of armies of seals. It is astonishing how many salmon one catches " adorned " with wounds made by seals. Even after they have reached the mouth of the river their main troubles are only just beginning. There are nets and more nets to be passed, and traps and cruives of every description. In addition the angler tries to stop as many as he can by artfully placing before them tempting-looking flies and baits of various kinds—sand-eels, gudgeon, golden dace, prawns, and even worms. The assortment of lures used by the fisherman are almost as numerous as the stars in the heavens. I may add that all this assortment is quite unnecessary, but that is another story. Luckily, perhaps, the angler is not able to do so much harm as he would like, for whether salmon do or do not feed in fresh water, there is no doubt that they do not require any nourishment while they are in the river. The enormous store of fat accumulated in the sea is sufficient to sustain them for very many months.

Then; too, they have further difficulties to contend with—falls and other obstructions, both natural and artificial. There are heavy rapids and streams up which they have to fight their way before they reach the spawning grounds. It is really a marvellous instinct that compels them to struggle against all these difficulties. The persistence of a salmon in trying to surmount a fall is wonderful. I once watched a fish jumping almost continuously for nearly an hour at a fall about 6 feet high. The salmon is a blundering idiot at the best, for if this particular fish had only waited for a couple of hours it would have been able to swim up this obstruction, when the tide had risen and had raised the level of the water below the fall. I often say that if a salmon had the brains of a chub we should never land one.

POACHING.

When the spawning grounds are at last reached one might have thought that there the poor brutes might be left in peace. But no. Mankind are always doing what they can to destroy the race. Poachers, armed with gaffs and spears, come out in gangs and do their best to prevent the fish reproducing their species. The salmon begins to lose in weight and condition as soon as it leaves the sea. The effort of struggling up the river is a further drain on the store of fat, and this is again further depleted by the building up of the milt and ovaries. Therefore, in the late autumn a salmon has the poorest value from a food point of view, but is then of the greatest value as a breeder. A salmon which survives until October or November is an almost certain spawner, and is therefore of the very greatest value for our future supplies of fish. It is quite time that it was recognised that anyone who destroys a salmon just about to spawn is committing a crime against the future welfare of the community. A hen-fish of 20 lbs. will have about 17,000 eggs, every one of which is a possible salmon. To destroy such a fish is like killing a cow when she is in calf. In the same way, the destruction of the small salmon-parr when they are in the river is like killing a calf when it is only a few weeks old. If we kill our cows when they are in calf, we cannot expect any cows, and, if we destroy the calves as well, we must not expect either cows or calves in the future.

POLLUTION.

The poacher is, however, not the greatest destroyer of the race. The capitalist is a far worse enemy. The damage caused by pollution is infinitely more serious than that done by poachers, for it works in several ways. In the first place, mature fish may be killed by pollution either from manufactories or from sewage, though I am inclined to think that the latter is the worst, for there is more of it, and it absorbs the oxygen from the water, without which the fish cannot breathe. Then, again, the deposit of filth and silt on the bed of the river destroys the insect and vegetable life which is required to feed the young fish from the time they are hatched until they reach the smolt stage. There is also another serious evil. The upper reaches of a river may be absolutely pure, but the lower part may be so badly polluted as to be little less than an open sewer. I allude particularly to the Usk and the Tyne, both of which were once most productive rivers. When the migratory instinct seizes the small parr and they commence their journey to the sea, they just have to obey orders, and they pay little regard to the height of the water. Their time has come and off they go. It may happen that, during their migration, the river is very low, and there is insufficient fresh water to overcome the effects of pollution. When this happens and they reach the polluted bottle-necked area at the mouth of the river, they are destroyed in thousands, and consequently there is a poor supply of salmon in future years. This is the main reason of the great falling off in the salmon harvest of these two rivers. The Usk rod-catch has been as high as 5000 salmon in a single season. Nowadays, 1000 fish is considered a good catch. In the same way the net-catch in the Tyne has fallen off from over 100,000 to less than 20,000 fish per annum. Let us hope that the recently appointed Pollution Committee may be able to do something to diminish this evil. Of course, industry must go on ; but there is no doubt that a great deal of the pollution which exists to-day could be avoided.

Salmon Spawning.

In the majority of our rivers most of the spawning takes place in the upper waters from October to January. In the Wye the bulk of the spawning takes place in November. The operations are usually carried on in strong streams about 2 to 3 feet deep. The fish do not like sand, and they generally select streams with fairly large gravel and stones—say up to the size of large potatoes. A rocky bottom is useless for spawning. The hen-fish does the bulk of the work, as most of the cock-fish spend much of their time in the glorious old game of fighting. It is no unusual thing for one cock to kill another during the spawning operations.

When the hen-fish is about to spawn she swims up a yard or two and comes up to the surface of the water. She then throws herself on one side and arches her body with the belly curved outwards. Violent convulsions then pass through the whole body of the fish from the tail upwards, and this throws up quantities of gravel and silt. It is at that moment the eggs are extruded, and these being heavier than water immediately sink to the bottom and settle in the crevices amongst the stones and gravel. Occasionally the cock-fish sidles up alongside her, but I have never seen the male salmon " throw itself." After these convulsions the lady drops back to the top of the " redd," or spawning-bed, where there is usually a hollow or deeper place, which has been cut up by her operations. These convulsions are repeated every three or four minutes, and, as she moves up a little higher each time, she gradually " cuts and covers " a sort of trench up through the gravel. This may go on for about a week or longer, and ultimately she digs up a bed, which is sometimes 3 or 4 yards long.

The most favourite places are rapid streams with a deep pool close by, to which the fish can retire when they are resting or have been frightened off the redd. I am told by the bailiffs that the principal time for spawning is in the late evening when it is dark, but I have seen fish spawning at all times of the day. After the spawning is completed the cock-fish will remain and guard the bed for a week or so, but if there is a fresh run of salmon he may attach himself to another lady, and go through the whole business for a second, or even for a third time. The mortality after spawning is very heavy, and particularly so with male salmon, and very few of these latter survive to spawn a second time.

HATCHING OF THE OVA.

I believe that a very large number of the eggs—possibly more than half—are not even fertilised. Then, again, there are other dangers to contend with. Trout are always busy when salmon are spawning, and I have seen them darting about within a yard of the hen-fish, trying to catch the eggs before they sink to the bottom. Then, again, we may get low water, and some of the redds will be left high and dry, and if this is accompanied by severe frost, the ova will be destroyed. Or there may be very heavy floods which will sweep away the gravel, eggs, and everything. No wonder Nature has to be so prodigal to provide for the enormous loss which takes place. To paraphrase the poet—

> "of fifty thousand seeds,
> she often brings but one to bear."

If all the eggs which were deposited in any one river were to become mature fish, the river could not hold them.

After about three months the eggs hatch out, and the tiny salmon (or Alevin, as it is then called) is less than an inch long. It has attached to it a sort of yolk-sac, and it is quite a helpless little creature. It eventually wriggles up through the gravel, and there it remains subsisting on the yolk-sac, which is gradually absorbed. This stage lasts for about six to eight weeks. (Plate IV., Figs. A and B.)

Commencement of Feeding.

Shortly before the contents of the yolk-sac are entirely absorbed, the Alevin, or rather the Fry, commence to feed on tiny insects. I should, however, draw attention to the fact that feeding does not commence until about five months after the egg was first deposited in the river. The length of this period depends a good deal on the temperature of the water, and in very cold rivers the length of time before feeding commences will be prolonged. This, again, is a wonderful provision of Nature. If eggs deposited in November were to hatch out, say, in December, and if the small fish required food immediately, it would probably die, for there would be very little food for it. As it is, the eggs do not hatch until February, and no food is required until about April, when food-supplies are more plentiful. Nature therefore arranges matters to suit the food conditions.

FRY.

As far as I can tell, in the Wye feeding commences about March or April. I have made a systematic collection of salmon fry and parr in our water at Hampton Bishop for a number of years, but I have not succeeded in catching any of the fry until May, and only three specimens in that month. The lengths of these three were — $1\frac{5}{16}$, $1\frac{3}{8}$, and $1\frac{7}{16}$ inches. They all had scales on them which showed from two to four rings of growth. It is probable that feeding had commenced earlier, but that the fish were then so small that they passed through the meshes of the net. At this stage the characteristic "finger-marks" are quite noticeable on the sides of these tiny little fish. At the end of May and in June, when there is more surface food, the fry will often be seen darting about on the surface of the water, and they now begin to grow more rapidly. I give below the length of the fry during their first year's growth :—

LENGTH OF FRY IN INCHES.

	Minimum.	Average.	Maximum.
May	1·3	1·4	1·5
June	1·4	1·9	2·7
July	1·6	2·2	3·4
August . . .	1·9	2·6	3·5
September . . .	2·1	3·0	3·9
October . . .	2·0	3·1	4·6

After October, as the food-supply begins to fall off, feeding diminishes and possibly ceases altogether, and the fish hibernate in crevices and snug spots. I have often found them in November under stones, and then they were usually almost black in colour.

PARR.

When their second year comes round they commence feeding again about March or April, but in the Wye some of the larger and more precocious Fry will then be seized by the migratory instinct and will go off to the sea as Smolts. In May and June, when there is a good hatch of fry, it is a wonderful sight to see these greedy little fellows—then about 3 inches long—darting all over the place in shallow streams. They have now assumed the true colouring of the salmon parr, and it may be useful to you to know how to distinguish parr from small trout. (Plates IV., Fig. c, and Plate V.)

1. The parr is more slender and graceful in shape, and especially about the head and tail, and the tail itself is much more V-shaped. The trout is clumsy looking as compared with the parr.
2. There are usually eight or nine " finger-marks " on the parr, and these are much more regularly placed than in the trout, and there is usually one well-marked red spot between each bar.
3. The trout is more spotted, and the red spots are more numerous and more irregularly placed.
4. The adipose fin of the parr is dark bluish-brown in colour, and in the trout is usually tinged with orange or red.
5. There are only one, two, or three—rarely more—well-marked distinctly black spots on the gill-covers of the parr, whereas in the trout there are numerous brownish spots on the gill-covers.
6. The maxillary bone on the upper portion of the mouth of the parr is comparatively short, and does not reach behind the back of the eye, whereas in the trout it

usually projects beyond a perpendicular line drawn downwards from the back of the eye. In other words, the trout has a larger mouth.

7. The fins of the parr are more delicately shaped, and are usually longer than those of the trout.

The following are the particulars of the lengths of the second-year parr taken at Hampton Bishop :—

LENGTH OF PARR IN INCHES.

	Minimum.	Average.	Maximum.
April . . .	2·0	3·2	4·2
May	2·6	3·6	5·2
June	2·7	4·1	6·8
July	3·0	4·6	5·9
August . . .	3·9	4·9	5·9
September . . .	3·9	5·1	6·3
October . . .	4·2	5·3	6·3

I should point out that it does not necessarily follow that the second-year fish caught at Hampton Bishop in any particular year are of the same group as the first-year fish caught in the preceding season. There is, I believe, a certain amount of migration amongst parr, and I should think it is more than probable that the general tendency is for them to work downstream rather than upwards. This is difficult to prove, but I have noticed that the inner portion of the scales, formed during the first year of life, is distinctly smaller in the second-year fish caught in April and May, than was the case with the first-year fish caught in the preceding October. From this it would appear that these second-year fish have come from the upper part of the river, where the feeding was not so good, and that our first-year fish have gone lower down the river.

SMOLTS.

In the following spring, that is, at the commencement of their third year of life, Nature again intervenes and gives orders to the great majority of the Parr, that it is high time that they were off to the sea. In the Wye migration commences in March, and, as a rule, finishes in May, but some may be found in the lower reaches of the river as late as June. The Wye is 150 miles long, and the smolt journey may take a considerable time for those fish which start their journey from the upper waters. As mentioned before, a few of the Parr migrate when they are only twelve months old, but the great majority reach the Smolt stage just after they have completed their second year of river-life. Some few may remain in the river for a third year before they are sufficiently matured to undertake this journey to the sea.

The rings or ridges, which are gradually added to the scales, are permanent. Consequently, by examining the scales of a mature fish, when it returns from the sea to the river to spawn, one can ascertain how many years it spent in fresh water before it reached the Smolt stage. Usually there is no difficulty in deciding as to when the fish first reached saltwater, for in the sea there is an enormous amount of food, and of a much more nutritious quality than is to be found in the river. Consequently the rings added to the scales when the smolt begins feeding in the sea are much more distinctly marked and much wider apart than those formed in the river. (Plate II., Figs. A and B.)

In the Wye the various classes of Smolts are approximately as follows. About 6 per cent. of the Parr migrate when they are only twelve months old, but the large majority—about 89 per cent.—reach the Smolt-stage when they are two years old, and about 5 per cent. remain for a third year in the river before they migrate to the sea.

Divided Migration.

Professor Knut Dahl has shown that in Southern Norway the majority of the Parr migrate as Smolts when they are two to three years old, but in the rivers further north the greater number remain in fresh water for four or five years. This divided migration is, I believe, simply a question of nutrition. In the south, where there is a longer summer and a longer period for feeding, the Parr mature earlier and migrate at a younger age. On the other hand, as one goes further north the summer is shorter, and there is less time for feeding, and consequently the Parr take a longer time to reach the Smolt-stage. For example, of the scales which I have examined from Dee salmon—a cold river—34 per cent. migrated as Smolts when they were three years old, and nearly 2 per cent. remained in the river for four years. In the Wye, which is a warm river, out of over 15,000 fish examined I have only found two salmon which had taken four years to reach the Smolt-stage. In the same way, in still warmer rivers, such as the Hampshire Avon, I have no doubt that it will be found that a comparatively large number of Parr will migrate when they are only twelve months old.

It is rather remarkable that the time spent in the sea before returning to spawn depends to a certain extent on the number of years of river life. The longer a Parr remains in the river the less time it will spend in the sea, and *vice versa.* Therefore, if the Smolt is only twelve months old, the probability is that it will remain for two and a half to three years or more in salt water before it comes back to the river to spawn. On the other hand, those Parr which spend three years in the river will have a comparatively short sea-life. It equally follows that, if it was in our power to do so, we ought to do everything possible to protect this early maturing type of fish. In the Wye, and in many other rivers, there are swarms of pike and chub and other predatory fish, to say nothing of anglers (?) who catch these small salmon and pretend that they are trout. It therefore stands to reason that the longer the Parr remains in the river the greater danger it runs of being killed by some means or other, and that there is far more probability of the one-year-old Smolt eventually becoming a mature salmon.

Colouring of Parr and Smolts.

The typical colouring of the Parr is due to pigmentary deposit on the true skin lying underneath the scales, which at first are transparent. When the migratory instinct seizes the fish a gradual change takes place in the thin skin or mucous membrane, which covers each of the scales. This gradually becomes more and more silvery and less transparent, and eventually it completely hides the parr-colouring underneath. This can easily be proved by scraping off the silvery scales from a smolt, and it will then be found that the original parr-colouring is still to be seen on the skin underneath. (Plate V.) This interesting fact was first discovered by Mr. Scrope—another Scotchman—and was mentioned in his book, which was first published in 1843. Considering that in those days scale-investigation was unknown, and that it was impossible to arrive at the true facts of the life-history of the salmon, the statements and ideas contained in that interesting book were almost prophetic. An excellent new edition has just been published.*

"Marking" Smolts.

When the small salmon reaches the Smolt-stage it is large enough to be "marked," and this is usually done with a tiny ring or with fine silver wire, and a large number of smolts have been marked in various rivers. With a few exceptions, all of these "marked" fish have been recaptured in their own rivers. This extraordinary "homing instinct" is another of the many wonderful things in Nature.

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* "Days and Nights of Salmon Fishing in the Tweed," William Scrope, Herbert Jenkins, Ltd., London.

In his earlier investigations, Mr. Johnston had to work almost entirely by theory, for there were very few *facts* to guide him. After he published his first paper, 5500 smolts were marked in the Tay in the spring of 1905. None of these were recaptured that year, but some were caught in each of the following years. The "mark" showed definitely when these recaptured fish had migrated to the sea, and consequently, when they returned, one knew exactly how long each fish had spent feeding in salt water. It is more than coincidence that the scales of every single one of these salmon showed the exact markings which Mr. Johnston's theories would lead one to expect. One could not have a clearer case of practice supporting and confirming theory. Let us take off our hats to Mr. Johnston for his wonderful and more than useful discovery.

Sea-life.

You will gather from the foregoing that the river-life of salmon may extend from one to five years. Up to the Smolt-stage they are more or less under our observation, but, until recently, we were almost entirely ignorant of the real facts of their sea-life. We knew, or rather guessed, that they did not hang about the coast, but went out to "the blue," but that was about the full extent of our knowledge. There was a sort of general impression that the Smolt returned to the river as a Grilse after a few months spent in the sea, and after spawning it would go back to the sea as a Kelt, and would return again and again to spawn in subsequent years, and on each occasion would be larger and heavier. All we really knew was that the sea provided the rich feeding by means of which the Smolt would eventually grow into a big fat salmon.

Thanks to Mr. Johnston, we now know that this was far and away from the truth. Scale-examination has proved that the great majority of salmon are returning to the river to spawn for the first time, and that a very small proportion survive to spawn a second time. In other words, the salmon harvest depends mainly on Maiden-fish, which have not spawned before, and less than 10 per cent. of the catch are salmon which are returning to the river to spawn for the second or third time. In the Wye the number of fish with " spawning-marks " on their scales is just under 7 per cent.

Mr. Johnston's discovery has also revealed the fact that salmon do not all spend the same time in the sea before returning to spawn. Some will come back after little more than twelve months feeding in salt water. A larger number will remain there for two or three years before they undertake their first—and possibly their last—spawning journey, and a few may stay in the sea for four, or even for five, years before attempting to reproduce their species. These latter are the exceptionally heavy fish weighing 30 lb. and over. The heaviest salmon of which I received scales weighed 74 lb. This was caught in a net in Norway, and was six years old, having spent two years in the river and four years in the sea.

ALL GRILSE SPEND ONE WINTER IN THE SEA.

It was formerly supposed that Smolts, which went down to the sea in the spring, returned as Grilse in the summer and autumn of the same year. Mr. Johnston has absolutely knocked this idea on the head. With very very few exceptions, all salmon remain in salt water for at least one winter. The odd ones which do return earlier are so exceptional as to be almost unknown. I have seen and handled many hundreds of salmon in my life, but I have never seen one in the intermediate stage between the Smolt and the Grilse, and I have seen scales from only three fish in this stage of their life, and none of these were caught in a river.

CLASSES OF WYE SALMON.

As I mentioned before, the salmon, which run up the Wye each season, have not all spent the same number of years feeding in the sea. This applies to most, if not to all rivers. Salmon can be divided into two main classes—Spring-fish, which return to the river in the earlier months; and Summer- or Autumn-fish, which come back later in the year. There is one important difference between these two classes of salmon. Spring-fish have, I believe, done no feeding in salt water in the same year in which they return to the river to spawn. As far as I know, salmon do not, as a rule, do much, if any, feeding in the sea during the winter, and it is therefore probable that Spring-fish have not had any food worth speaking of since the previous October or November. No one has yet found any food in the stomach of a Spring-fish. I have examined several, and the only things I have found were some tape-worms—uneasy occupants for an empty stomach. Summer-fish, on the other hand, have frequently been feeding almost up to the time of their entering the river, and recently taken or partially digested food is often found in their stomachs. Their scales invariably show—sometimes few and sometimes many—wide summer-rings surrounding the last winter-band, clearly indicating recent feeding. (Plate VI., Fig. B.) On the scales of Spring-fish such rings are absent. (Plates VI., Fig. A, VII., Figs. A and B.)

Each of these two main classes can again be sub-divided into three sub-classes, according to the length of time spent feeding in the sea, as follows:—

	Sea-feeding, Years.	Average Weight, in Pounds.
Summer-fish—		
Grilse	1½	5·5
Small summer	2½	12·3
Large summer	3½	23·6
Spring-fish—		
Small spring	2	11·4
Large spring	3	20·7
Very large spring	4	34·3

One occasionally comes across an odd salmon which has remained for five years in the sea without spawning, but such fish are very rare.

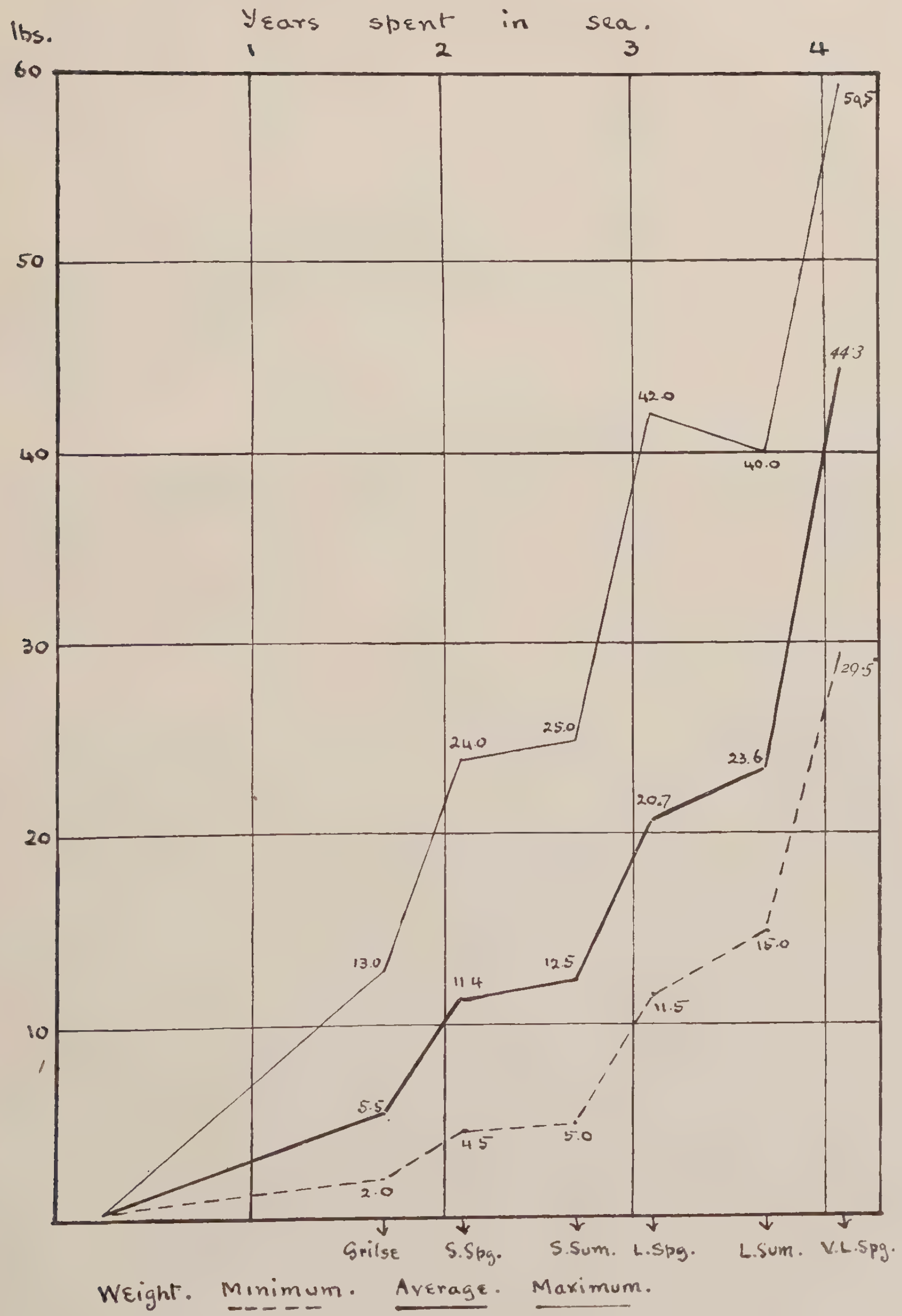
All of the above are "maiden-fish" which have not spawned before. I will deal with the "spawned-fish" later.

Now all the Smolts are more or less of the same size, varying between 4 and 6 inches. It will be seen from the above that the ultimate size of a salmon depends almost entirely on the length of time spent in the sea. If they return as Grilse after feeding in salt water for a little over a year, they will only weigh about 5½ lb. On the other hand, if they remain for four years in salt water without spawning, their average weight will be just over 34 lb.

Perhaps the accompanying table will make this clearer. From this it will be seen that Spring-fish increase more rapidly in weight than Summer-fish. This is due to the fact that the best feeding in the sea is during the latter part of the summer, and those salmon which return to the river in the summer miss this, whereas those fish which remain there feeding for another few months put on proportionately more weight.

I will now deal separately with each class of salmon.

TABLE I. GROWTH IN SEA.



GRILSE.

Grilse very rarely show in the Wye before June, but the main run is in July. There is a slight falling off in numbers in August, and afterwards they are few and far between. Their scales all show the same markings, namely, one summer-zone, one winter-band, and part of the next summer-zone. (Plate III.) This last, as might be expected, will vary according to the time of their return. Those which return early in June show only a few rings of summer growth, but those which remain in the sea until September or later will have a far larger number of such rings. In the same way, owing to a longer period of feeding, the average weight increases in each month. The following are the weights of the hen-fish only. I have omitted the males, as their numbers are hardly sufficient to give a fair average :—

GRILSE : AVERAGE WEIGHT IN POUNDS.

	June.	July.	August.	Sept.	Oct.
	4·6	5·2	5·8	7·3	8·5
Increase . .	—	·6	·6	1·5	1·2

There is one very remarkable fact in connection with the weight of salmon, which applies practically to all rivers and to all classes—and that is the great variation in weight of fish of the same age. As I mentioned above, the average weight of Wye grilse is about 5½ lb., but they vary in weight from 2 to 13 lb. It may be partly due to variation in feeding-grounds in the sea. One fish may be lucky and find a good spot in which to gorge and guzzle, whereas another may get into regions where food is less plentiful. There is also a good deal of variation from season to season, probably due to varying conditions in the sea. I understand that herrings form the principal food of salmon, and in some years the supply is more numerous than in others, or the herrings may have taken themselves to different feeding grounds.

There is, however, another factor to be considered, and this is probably the most important one. The parent fish are not all of the same size, and there is, in addition, great variation in rearing grounds in the Wye. The Upper Wye above Rhayader has a very poor supply of food as compared with the Irfon and Ithon, which are the two most important tributaries for spawning. Also, some fish are born in the main river, where there is a still larger food supply, but against this there we find swarms of pike and chub. It seems to me only logical to assume that the conditions of early life must affect the growth of the salmon throughout all the subsequent years. A poor calf will never make a good cow, and in the same way a parr, which has had a bad start in life, can hardly be expected to grow into a big, well-shaped salmon. It also seems more than probable that very much depends on the parentage. A poor cow is less likely to produce a big calf than a well-grown mother coming from a good stock. Professor Knut Dahl has proved, in connection with trout, that the larger the female parent, the bigger the eggs, and the greater the growth throughout the whole of the rest of life.

I am sorry to say that in the Wye, as is the case in many other rivers, Grilse seem to be gradually disappearing, and it is difficult to say what is the cause. It may be that the fish are changing their habits and are remaining longer in the sea before they return to spawn ; or possibly we are killing out the race which produces Grilse.

RACES OF SALMON.

I am firmly convinced that, although all our salmon belong to one species, *Salmo Salar* (the true Atlantic salmon), there are many types, varieties, or " races." It is generally admitted that each river has its own particular " race." For instance, age for age, the Tay race is large and that of the Helmsdale small. Generally speaking, large rivers produce big fish, and in small rivers the general type is small. Then, again, in the Dee, which can hardly be called a small river, the Small Spring-fish only average about 7½ lb. as compared with an average of about 11½ lb. in the Wye; but the Autumn-fish in the Dee are big heavy salmon of an altogether different shape and type. In the same way, in the Cumberland Derwent, which is quite a small river, the Small Summer-fish average nearly 17 lb. as compared with 12¼ lb. in the Wye. These Derwent salmon are also much better shaped and shorter and thicker than the same class in the Wye. In the latter river the Small Summer salmon have an average "condition-factor" of 35·9, that is, 4·1 (or 10¼ per cent.) *below* Mr. Corbett's standard factor of 40. The Derwent factor for this class is 41·7, or 1·7 (4·2 per cent.) *above* the standard.

Admitted, then, that each river has its own type or race, it is only a step further to assume that there may be several races or types in any one river. Probably each tributary will produce its own type. Further, I believe that, generally speaking, each class of salmon will reproduce its own class. In other words, Spring-fish will breed Springers, and the offspring of Summer-fish will return to the river in the summer. I will go still further. It seems to me probable that the offspring of, say, Large Spring-fish—namely, those which remain three years in the sea before spawning—will also adopt the same habit of migration, and that this will apply to each of the various classes of salmon. Otherwise it is difficult to explain the fact that, year after year, with, of course, some variations, we have always two predominant classes of salmon in the Wye—the Small Summer-fish, which spend about two and a half years in the sea; and the Large Spring-fish, which remain there for three years before they return to spawn. These two classes together make up on the average 70 per cent. of the total catch. If any one class of salmon produced indiscriminately various other classes, how can one explain the fact that, year after year, the relative numbers of these two classes vary so little as compared with the total catch ? Or, again, how is it that the Large Summer-fish, which spend about three and a half years in the sea, seldom amount to more than 2 per cent. of all the salmon landed in the Wye in any one season ?

Let me say at once that I do not for one moment pretend to be the originator of this idea. I think I first heard of it from the late Mr. William McNicol. I know that he was firmly convinced of the truth of this theory, and he gave me several *facts* which to me were most convincing. I know of no man who had so great a practical knowledge of salmon and of their habits. In his own words : "Like breeds like, and summer-fish can't be expected to produce springers." He was also of opinion that the female was the predominant parent, and that the habits of the offspring were not so much affected by the class to which the male parent belonged. His premature death is a very great loss to the community, and I cannot let this occasion pass without expressing the great debt of gratitude which I personally owe to him. Most of what I know I have learnt from him. Again I say—all of us who are interested in this great question owe very much to Scotland.

Small Spring-fish.

The next class I have to deal with is that of the Small Spring-fish. Their scales, like those of the Grilse, show a summer-zone and a winter-band, indicating a whole year spent in the sea, and outside this there is a second summer-zone, indicating a complete summer's feeding, and this is surrounded by a second winter-band. (Plate VI., Fig. A.) Let me put it in another way. Their scales are similar to those from Grilse, with the additional rings corresponding with the longer period spent in the sea.

There is, however, a considerable difference in the character of the two classes. The Small Springers have had the full benefit of the extra food of the late summer. The average Wye Grilse has spent eighteen months in the sea, and in that time has increased from about 2 ounces to 5½ lb. in weight. Small Spring-fish weigh on the average nearly 11½ lb., and have, therefore, added 6 lb. to their weight in the additional six months of sea-feeding. In other words, in six months they have rather more than doubled the weight which took the grilse eighteen months to acquire. The condition-factor of small springers is 36·2 as compared with 34·4 for Grilse. They are therefore thicker and shorter fish. Their flesh is also much richer in fat, but this applies to all spring-fish as compared with those which run in the summer or autumn.

Small Spring-fish vary in weight from a minimum of 4½ lb. to a maximum of 24 lb., and the 2318 examples of this class, which I have investigated during the last sixteen years, averaged 11·4 lb. Up to 1924 the smllest fish I had come across in the Wye of this class weighed 5½ lb. This year (1923) I received scales from an exceptionally small specimen weighing only 4½ lb. It was caught at Winforton, on April 28, and the angler rather naturally thought it was a Grilse, and sent me the scales as an example of an extraordinarily early-running fish of this class. The scales, however, showed two complete years spent in the sea, and there was no doubt that it was an exceptionally small specimen of its class. This is the *smallest salmon*, as opposed to Grilse, which I have come across in the Wye. It is rather remarkable that it was caught in the same part of the river, and I believe in the same pool, as Miss Davey's 59½ lb. fish, which, again, is the *heaviest* salmon caught in the Wye during the last quarter of a century.

These fish begin to run in February and March, but only in small numbers. The main run is in April and May, which months make up 61 per cent. of the total catch. Afterwards they fall off rapidly in numbers. Unfortunately these beautiful little salmon are none too plentiful in the Wye, which is a pity, as they are most sporting little fish to catch, and are of the best size for the market. In the Wye they amount to only just over 15 per cent. of the total catch. It is rather interesting to note that in the Dee the conditions are quite different. I understand that in this river they are much the most numerous class. Of the examples of Dee fish which I examined in 1922, there were 162 small springers out of a total of 263, or a proportion of 61·6 as compared with 15·3 in the Wye. It would be unwise to lay too much stress on the figures of the catch of one season only, but I am told that the above is about the usual proportion. The average weight of these Dee fish was 7·6 lb. as compared with 11·4 in the Wye, and the condition-factors were 34·6 in the Dee and 36·2 in the Wye.

SMALL SUMMER-FISH.

The Small Summer-fish have similar scales to the Small Springers, but surrounding the second winter-band are a number of open summer-rings indicating recent feeding in the sea. (Plate VI., Fig. B.) They first begin to show in April, and these earlier fish have very few summer-rings—sometimes only two or three—which seems to indicate that feeding in the sea does not commence before March or April. I have come across a very small number of Wye salmon with summer-rings on their scales before April. This class begins to run in larger quantities in May, but the really big run is in June and July, which two months account for over 56 per cent. of the total catch of this class. As might be expected, these later running fish have a far larger number of summer-rings. In August the numbers begin to fall off, with a still smaller quantity in September, and under ordinary circumstances on October 15th, when the season closes, the run is practically over. Naturally, in dry summers there will be larger numbers of fish still remaining in the sea after the end of the season. There is nothing to prevent a salmon from entering the Wye and swimming up the river for 100 miles or more, even in very low water. The fact, however, remains that unless there are occasional floods, salmon will not enter the river, or, at any rate, will not go very far up it. That is the danger to be feared from water schemes, which involve impounding and holding up the water. They tend to eliminate the summer freshets, which are absolutely necessary to induce salmon to run up to the middle and upper reaches of most rivers.

The average weight of this class in the Wye is 12·5 lb., and they vary from a minimum of 5 lb. to a maximum of 25 lb. It should be noted that although on the average they have spent about six months longer in the sea than the small springers, the increase in average weight is only just over 1 lb. I cannot make any comparison with the same class from the Dee, for in this river there seems to be only a very small run of summer-fish. On the other hand, in the Wye they form the second most important class of salmon, and amount to 32·3 per cent. of the total catch. The Wye nets depend for their harvest on these Small Summer-fish. It has, however, always been the policy of the Wye Board of Conservators, and of the Wye Fisheries Association, who manage the netting, to restrict the netting of the spring salmon, for we believe that they are the best class for breeding purposes, and especially so if the above-mentioned theory is correct, that "like will produce like."

LARGE SPRING-FISH.

I now come to the Large Spring-fish, which is the most important class of salmon in the Wye, and for which the rod-fishing is rightly famous. Out of 15,200 sets of scales examined during the last sixteen years, 5680, or 37·3 per cent., came from Large Spring-fish. Most of them are five years old, having spent two years in the river and three years feeding in the sea. Their scales are again similar to those of Small Summer-fish, with the addition of a complete zone of wide rings formed during their third summer spent in salt water, surrounded by a third winter-band. (Plate VII., Fig. A.) They vary from a minimum of 11½ lb. to a maximum of 42 lb., and they average 20·7 lb. It is rather remarkable that in recent years their average weight has been going down, and this is shown in both sexes, as will be seen from the following figures :—

LARGE SPRING-FISH : AVERAGE WEIGHT IN POUNDS.

	Females.	Males.	Total.
4 years ending in 1911 .	20·8	24·9	21·9
,, ,, 1915 .	19·9	24·8	21·4
,, ,, 1919 .	19·8	23·2	20·9
,, ,, 1923 .	18·7	22·0	19·5

In 1922 I received seventy-six sets of scales from the Dee of salmon of this class out of a total of 263, or 28·9 per cent. I understand that in that season the proportion of large fish was rather above the normal. The average weight was 17·1 lb. as compared with 20·7 lb. in the Wye, though the average in the latter river in 1922 was only 19·7 lb.

In seasons with mild winters these fish begin to run in December and January, and I have come across isolated cases of precocious salmon of this class, which were caught in the river in September and October. These fish, if they had not been captured, would not have spawned for over twelve months after entering the river. Usually there is no big run in February, but in March and April they enter the river in large numbers ; 25 per cent. of the total catch is made in March and 33 per cent. in April. The run falls off rapidly in May, and afterwards they are few and far between, though if we have low water in March and April there will still be large numbers left in the sea. If, however, we have good running water in May, the sea and estuary will be almost emptied of this class of salmon.

LARGE SUMMER-FISH.

The next class of salmon I have to deal with are comparatively rare in the Wye. Large Summer-fish, in that river, are conspicuous by their absence. They amount to only 1·9 per cent. of the total catch. I mentioned before that the principal difference between the scales of Small Spring- and Summer-fish was that, although both showed two complete years of sea-life, the latter had in addition a varying number of wider rings of summer-feeding, corresponding with the extra time spent in the sea. It is just the same with the Large Spring and Summer-fish. The scales of both classes record three summers and three winters spent in the sea, and in the case of the latter there is, in addition, a varying number of summer-rings.

The numbers examined of this class are too small to enable one to do more than merely indicate their general characteristics. The average weight is 20·8 lb., varying from a minimum of 15 lb. to a maximum of 30½ lb. Here, too, one must note that the comparative increase in weight over that of their brothers, sisters, and cousins of the same hatch, which returned to the river six months earlier, is relatively small. This is one of the important differences between spring and summer-fish, due, as I mentioned before, to the fact that the latter part of the summer provides the best feeding. The accompanying figures will probably make this clearer :—

AVERAGE WEIGHT AND INCREASE OF EACH CLASS OF SALMON.

	Approximate Sea-life.	Average Weight.	Increase.
Grilse	1½ years.	5·5 lb.	—
Small spring	2 ,,	11·4 ,,	5·9 lb.
Small summer . . .	2½ ,,	12·5 ,,	1·1 ,,
Large spring	3 ,,	20·7 ,,	8·2 ,,
Large summer . . .	3½ ,,	23·6 ,,	2·9 ,,
Very large spring . .	4 ,,	34·3 ,,	10·7 ,,

It will be noticed that in each case spring-fish increase more rapidly in weight than salmon which run in the summer.

The run of Large Summer-fish is approximately at the same time as that of the Small Summer race. It commences in April, increases in May, attains its maximum in June, and then decreases.

VERY LARGE SPRING-FISH.

I now come to the last race of salmon which return to the Wye without having spawned previously. Most of the Very Large Spring-fish are six years old, having spent two years in the river and four years in the sea without returning to spawn. (Plate VII., Fig. B.) This class is slightly more numerous than the previous one, but they are comparatively scarce, and amount to only 2·2 per cent. of the total catch. I believe this is the case in most rivers, and that is the reason why the much-desired " 40 pounder "—let alone the " 50-pounder "—is so rarely caught. The weight of a salmon mainly depends on the length of time a fish remains in the sea without spawning. The spawning instinct seizes most salmon after spending two to three years in salt water, and it is with only a comparatively small number that this overpowering impulse is delayed for another year. Very few salmon remain in the sea for more than three years without returning to spawn, and, as far as the Wye is concerned, the number which delay their spawning journey beyond the fourth year is almost infinitesimal.

The run of this class takes place at much the same time as that of the five-year-old Large Spring-fish. It commences in January and February, reaches its maximum in March and April, and then rapidly decreases.

The heaviest Wye salmon of which I have received scales is the magnificent fish of 59½ lb. caught by Miss Davey on March 13th, 1923. It was 52½ inches long and 29 inches in girth, and therefore had a condition-factor of 41·1, or 2¾ per cent. above

Mr. Corbett's standard. It is not only the heaviest salmon caught with rod and line in the Wye so far recorded, but is, I believe, the largest *spring-fish* ever caught by an angler in this country. Miss Ballantine's wonderful salmon of 64 lb.—not that I want to detract from it in the least degree—was an autumn-fish.

The average weight of this class is 34·3 lb., varying from a minimum of 19·5 to a maximum of 59½ lb. (prior to 1923, 52 lb.). Only 17 per cent. of those I have examined were hen-fish. It is comparatively rare for a female salmon to remain for more than three years in the sea without spawning, and that is why it is very unusual to catch a hen-fish weighing more than 30 lb., and usually females over this weight are mostly "spawned-fish."

Before I leave this class, I must mention the extraordinary corpse which was found in the Wye in 1920. Early in May an unfortunate angler got "smashed" by a very big salmon at Whitney, close to the spot where Miss Davey broke all our previous records. Later on, through an underground channel, I received the scales of a salmon which had been found dead at Belmont (just above Hereford and several miles below Whitney) about May 18th—59½ inches long and 33 inches girth. The scales showed two years river-life and five years spent in the sea. Unfortunately the finder, who probably did not realise that this was possibly a record salmon for the British Isles, returned it to the river. About a week later a report reached me that a "whale" was stranded at Even Pits, about 8 miles below Hereford. The head-bailiff brought it up to Hampton Bishop on May 27th for my inspection, but, as can easily be imagined, the fish was pretty far gone, and one had to keep well to the windward. This monster was in an advanced stage of decay, and much of the snout and lower jaw had disappeared. The remains were carefully measured and weighed as follows: Weight, 42 lb.; length, 57 inches; girth, 26 inches. The scales also showed five years' sea-life. It is so exceptional to find a salmon which has spent five years in the sea without spawning, that I feel little doubt that this was the identical fish previously found at Belmont, and which then measured 59½ inches in length. Further, in all probability it was the one which had been lost at Whitney some time before.

The question naturally arises as to what was the original weight of this monster, when it first entered the river. Taking Mr. Corbett's standard of 40, a 59½-inch salmon ought to weigh 84 lb. Generally speaking, Wye salmon don't quite reach this standard. I think, however, we can safely say that its original weight was certainly over 60, probably over 70, and possibly over 80 lb.

The heaviest Wye salmon, of which we have any authentic record, weighed 63½ lb. It was caught in a net on May 29th, 1905, and measured 55½ inches in length and 28½ inches in girth. This gives a condition-factor of 37·2. Miss Ballantine's 64-pounder was a much better-shaped fish, for it was only 54 inches in length, which gives a factor of 40·6.

In this connection, let me advise everyone who is interested in the question of the relative weight of a salmon of a given length to expend the small sum of 2s. 6d. in buying one of Mr. Corbett's "Condition-cards." * It is really a simple form of slide rule, which enables one at a glance to ascertain the "Condition-factor" of any fish one may capture. It was published by the Salmon and Trout Association, and can be bought at any fishing-tackle shop. It is based on the old mathematical formula that the weight of any cylindrical body varies with the cube of its length. Mr. Corbett has very wisely selected 40 as his standard. This has the double advantage, that it represents a good average salmon for the British Isles, and also is an easy

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* "Condition" Calculator. For Salmon, Trout and other Fish. Designed by E. M. Corbett. The Salmon and Trout Association, Fishmonger's Hall, London, E.C. 4.

figure to calculate with. It is a simple matter to multiply by 40, and every difference of one point represents a variation of $2\frac{1}{2}$ per cent. from the standard. I will give an example to show the method of working.

What ought to be the weight of a 30-inch salmon? Here is the formula :—

$$\text{Weight} = \frac{\text{Length (in inches) cubed} \times 40.}{100{\cdot}000}$$

Thus

$$30 \times 30 \times 30 = 27{\cdot}000$$
$$27{\cdot}000 \times 40 = 1{\cdot}080{\cdot}000$$
$$108{\cdot}000 \div 100{\cdot}000 = 10{\cdot}8 \text{ lb.}$$

Or, put it in another way. If a fish of 40 inches length weighs 25 lb., what is its condition-factor?

$$\text{Condition-factor} = \frac{\text{Weight (in pounds)} \times 100{\cdot}000}{\text{Length (in inches) cubed}}.$$

Thus

$$25 \times 100{\cdot}000 = 2{\cdot}500{\cdot}000$$
$$40 \times 40 \times 40 = 64{\cdot}000$$
$$2{\cdot}500{\cdot}000 \div 64{\cdot}000 = 39{\cdot}1.$$

The above are simple calculations, but when one has figures of salmon measuring, say, $35\frac{3}{4}$ inches in length, and weighing, say, $17\frac{3}{4}$ lb., the calculations involved are terrible. Therefore all one has got to do is to spend 2s. 6d. and to buy one of these cards, and all the work is done for one.

MAIDEN-FISH.

I have endeavoured to give you an idea of the various classes of salmon, which are to be found in the Wye, but so far I have only dealt with Maiden-fish, that is, those which have not spawned before. As will be gathered from the foregoing, although most of the Smolts are of the same size and age—namely, about $5\frac{1}{2}$ inches long and two years old—yet when they return to the river for the first time, they may weigh anything from 2 lb. to 50 lb. or over. It will further be evident that the weight of a salmon mainly depends on the length of time spent in the sea. Table I., on page 27, giving the minimum average and maximum weight of each class, and the period spent in the sea, will make this clearer.

This chart shows clearly the relatively more rapid increase in weight of Spring- as compared with Summer-fish. Generally speaking, the former are much richer in fat, which is probably an arrangement of Nature to provide for the longer time to be spent in fresh water, which is, for all practical purposes, a period of starvation. A spring salmon may enter the river in January, February, or March, spawn in November, and not return to the sea as a kelt until the following February, March, or April. Therefore a period of about twelve months passes, during the whole of which time it obtains no food worth speaking of.

On the other hand, the summer-fish usually enter the river in June, July, or August, spawn also in November, and get back to the sea in, say, March or April. It therefore has not so long a period of starvation as the spring-fish, and consequently does not require the same reserve of fat. Anyhow, spring salmon are much fatter than their cousins, which run in the summer, and they are much the more valuable class of salmon, whether for eating or for angling. All the more reason to take care of them, and to make certain that a sufficient stock of parent fish of this class are left each season to carry on the race.

FALLING-OFF IN CONDITION.

I now come to the most interesting part of the story, and that is the evidence afforded by the scales of the spawning journey. A spring-fish in the pink of condition is a fine handsome animal, but, owing to its taking no food in fresh water worth talking about, it falls off in condition everyday while in the river. Then, in addition, there is a further drain on the whole system of the fish to supply the necessary energy for running up the river. In rivers with steep courses and many rapids and falls this is very arduous work. On the top of this there is a further drain on this accumulated store of fat to supply the materials for building up the milt and ovaries. The latter may weigh as much as one-third of the whole weight of the fish. For example, the ovaries of a 21 lb. salmon will weigh about 7 lb. Then, again, the violent exertions of spawning use up a further amount of this store of fat. There is, in fact, a continuous drain on the whole system of the fish, and it is remarkable that the scales are also affected, and become much "worn" and disintegrated. (Plates VIII., Fig. B, IX., and X.) It has been suggested that they are partially absorbed to meet this heavy demand of material for the spawning journey and subsequent operations. Scales in the ordinary state have round even edges, but after spawning the outline becomes broken and uneven, and sometimes a good deal of the surface—including the rings—disappears. This is especially the case with cock-fish, so that in the autumn one can frequently distinguish the sex by examining the scales. Sometimes the scales are so much "worn" that they are no longer readable, and one can only guess at the age of the fish. I should mention that, as a rule, the posterior end of the scales of males is rather more pointed than that of hen salmon. Possibly the disintegration begins earlier (Plate VII.) with males, for as a rule during spawning the posterior end is the first to disintegrate.

I should point out that this "wearing" of the scales can take place in the sea as well as in the river, and is quite noticeable with fish caught in the nets in July. This is probably due to the fact that these fish have already commenced building-up their genital organs, and therefore the drain on their system has already begun. Again, this is more noticeable with cock-fish than with females. In the same way, the change in the colour of the salmon can take place in the sea as well as in fresh water, and one may catch fish in the nets which have never been in the river, but which are in full spawning livery.

KELTS.

After the exhausting labours of spawning, the spent fish, or Kelts as they are then called, drop back into quiet pools, where they remain for a long time gradually recuperating. I have known of one case where a fish remained in the same pool for three months. The whole of the functions of the body gradually recover, and the scales again become bright and silvery, and then they start on their return journey to the sea, some of them little better than living corpses. This second downward migration generally takes place in February, March, and April. I have never seen a kelt in our water so late as May, but I understand that there are a good many to be found lower down the river, nearer to the sea, in that month. I should think that after May there are very few kelts to be found in the Wye.

Sometimes they " plump up " very considerably, and are then spoken of as " well-mended " kelts. I believe this is not due to feeding, but is the result of absorption of moisture. Anyhow, if one kills a kelt by mistake, it will generally be found that this moisture soon evaporates, the flanks drop in and the appearance of " plumpness " disappears. I have examined the stomachs of a good many kelts, and I have never found any trace of recently digested food. Whether they do or do not feed in fresh water, I am quite sure that they do not do so to any great extent, as otherwise there would be nothing left in the river, for a couple of hungry kelts could soon gobble up all the contents of a single pool. I understand that in the sea a salmon can eat as many as five large herrings in a day. None of the scales from the best " mended " Kelts I have ever seen show the least trace of any new growth. I, for one, am convinced that Kelts take very little, if any, food while they are in the river.

It is worth noting that Kelts show quite visible development of the new ovaries for the next spawning operations, which may not take place for eighteen months, or even more. One also frequently finds several of the old eggs which have not been shed.

As far as I can judge, the migration of Kelts is only partially affected by floods. They go down when Nature tells them the right time has come, and not before. For instance, last February (1923) the Wye was in continuous flood throughout the whole of the month, and yet in March we caught just as many kelts as usual.

It is worth noting that during the last dozen years Wye salmon have become quite a month earlier in their habits. They run earlier, spawn earlier, and return earlier to the sea. Nowadays we catch comparatively few kelts in our water in April. Formerly this was quite a "kelty" month.

THE SPAWNING-MARK.

From the time the salmon first leaves the sea up to the kelt stage, it will lose about 40 per cent. of its original weight. Consequently, when it again reaches salt water, it is in a ravenous condition, and commences to feed greedily. This is shown by the addition of very broad well-marked rings around the broken edges of the old scales. Between the outer edge of the old scale and the new growth there is a sort of scar, which Mr. Johnston has aptly termed the "spawning-mark." When one finds such a mark on the scales of any salmon, it affords positive evidence that the fish has spawned before. (Plates IX., Fig. A, X., and XI.)

There are always plenty of people who scoff at new ideas and theories, but Nature has provided us with other evidence to confirm the truth of Mr. Johnston's theories. While in the river salmon are attacked by the fresh water gill-maggot. (Plate XIV., Fig. 1.) This little brute sticks its sucker into the gills of the salmon, and there it remains for the rest of its life. When the fish goes back to the sea as a kelt, all of these do not die.

Consequently, when the fish returns to the river to spawn for the second or third time, one will sometimes, not invariably, find some of these parasites still adhering to its gills, thus affording positive evidence of previous spawning.

Then, again, during the spawning operations salmon acquire a large number of additional spots and speckles on the gill-covers and along the sides, both above and below the medial line. (Plates XI. and XII.) Maiden-fish rarely have more than two or three spots on the gill-covers, and very few, if any, below the lateral line. These new spots do not disappear when the Kelt is recuperating in the sea, and they are sometimes so marked that I have seen them on fish in the water and before they were landed. As a rule, spawned-fish are exceptionally hard fighters, probably due to the fact that, generally speaking, they are not so fat as maiden-fish. Their flesh, too, as a rule, is paler in colour, and they are not so good to eat.

We have, however, further evidence to confute the doubting Thomas, and this is provided by mankind. On February 27th, 1914, I caught and marked a Kelt. It was then 33 inches long and weighed 8 lb. This fish was recaptured on the Lydney Sands (above the mouth of the Wye) on May 10th, 1915, with my mark (4632 Ireland) attached to its adipose fin. In the interval of fourteen months it had added 7 inches to its length, and was 40 inches long, and it then weighed 28 lb., having more than trebled its weight in that comparatively short time. And yet some people say that kelts are not worth preserving. I need hardly say that the scales of this salmon showed a spawning-mark.

Now, many kelts have been "marked," and some of these have been recaptured when returning to the river to spawn again. In every single case the scales showed a spawning-mark, thus fully confirming the absolute truth of Mr. Johnston's theory. I say without fear of contradiction that his theories have now been proved up to the hilt in every direction, and that, as far as salmon are concerned, the truth of the Scale Theory has been established beyond controversy. Let me add that there is plenty of room for more investigators, for we still have much to learn about the habits of this wonderful fish.

MORTALITY AFTER SPAWNING.

One of the most astonishing things which scale examination has revealed is the fact that in most rivers Spawned-fish are comparatively rare, and that the bulk of the catch consists of Maiden-fish returning to the river to spawn for the first time. It was formerly supposed that salmon spawned every year, and that they returned to spawn year after year, and were heavier and heavier with each successive visit. This idea is now shown to be untenable. Comparatively few salmon survive to spawn a second time, hardly any a third time, and it is an exceedingly rare occurrence to find a fish with three spawning-marks on its scales, that is, a salmon which was going to spawn a fourth time.

Out of the 15,200 sets I have examined from Wye salmon, only 1055, or 6·9 per cent., had spawning-marks. In other words 93 out of every 100 salmon are Maiden-fish. Of these 1055, 83 had two spawning-marks on their scales, and only three were returning to spawn for the fourth time. It is therefore quite evident that the Wye harvest depends to only a very small extent on salmon which have spawned before. This is, of course, due to the very great mortality after the arduous task of spawning. The salmon may be described as a very rapidly growing animal, which reaches maturity in from four to six years, spawns once, and then usually dies.

I should mention that this mortality is much heavier amongst the cock-fish. Of the above 1055 spawned-fish, only 58, or about 5½ per cent., were males. I believe the proportion is even less than this, for I find that anglers are more inclined to describe hen-fish as males than the reverse, and especially so with salmon which have spawned before, as they are frequently long and ugly fish.

SEX.

I always feel some doubt as to the " diagnosis " of sex based on external examination only. Autumn-fish are usually fairly easy, but in the spring it is more difficult. Perhaps the following hints may be useful. The head of the cock is usually slightly longer than that of the hen, and the snout is more pronounced. There is also a sort of " snarl " in the middle of the upper jaw, and the chin, or the end of the lower jaw, is rather squarer than that of the hen. Her head, as a rule, is more pointed, like the end of a torpedo. The male has, as it were, a fiercer look. Perhaps the photographs on Plates XII., XIII. and XIV., will make all this clearer, for descriptions are not easy things. As the season advances the cock develops a pronounced kip at the end of the lower jaw. As spawning draws nearer this becomes longer and longer, and sometimes penetrates through the skin on the top of the upper jaw. (Plate XII., Fig. B.)

The only way of being quite sure about the sex is to cut the fish open. In the early spring the milt of the male salmon is usually quite undeveloped, and all one can see are two long ducts lying close to the roof of the abdominal cavity. With the females the ovaries are always more or less developed. In a 20 lb. spring-fish they will be about 6 inches long, but the eggs will only be of the size of pin-heads. These will get larger and larger as the season advances, and just before spawning they will be about the size of peas, and the ovaries will almost entirely fill the abdominal cavity. (Plate XIV., Fig. B.) In the same way the milt will develop in the cock-fish, and it is easily recognisable, as it is very similar to the " soft roe " of the herring, but of course on a larger scale. Whenever I have to cut up a fish, I always make a point of confirming, or otherwise, one's previous " diagnosis " of sex. I am glad to be able to say that it is not often " otherwise."

The above also applies to the small parr, for their ovaries are slightly developed even before they leave the river, but they are very minute, and a magnifying glass will be of assistance. The male parr sometimes develop their milt to the full extent while they are in fresh water, and it has been proved by experiment that the ova of mature salmon can be fertilised by their milt. Probably another arrangement of Nature to provide for a possible scarcity of cock-fish at spawning-time. I believe the female parr has never been known to ripen its ova in fresh water under natural conditions.

The figures—for whatever they are worth—of the proportion of the sexes of Wye salmon are as follows :—

	Males.	Females.	Total.	Proportion of Females.
Grilse	227	399	626	63¾ per cent.
Small spring	531	1787	2318	77 ,,
Small summer	1450	3453	4903	70½ ,,
Large spring	1639	4041	5680	71 ,,
Large summer	118	171	289	59¼ ,,
Very large spring	272	57	329	17¼ ,,
Spawned fish	58	997	1055	94½ ,,

In this connection it is a rather remarkable fact that, in all classes of maiden-fish, the hens run first and the cocks later. This seems to be another provision of Nature to ensure that both sexes will arrive at the spawning-beds at the same time. As the ova become more developed and heavier, it will be more difficult for the female salmon to surmount rapids or to jump over obstacles and obstructions. The cock-fish, on the other hand, being more powerful, will have less difficulty in overcoming these difficulties. Taking the three principal classes, the percentage of males in the total catch of each class in the various months is as follows :—

Percentage of Male Fish.

	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
Small spring .	19½	16	19¼	23¾	28	36	—	—
Small summer .	—	—	20	23	29½	30	36	39¼
Large spring .	16¾	15¾	19½	33¾	43¼	51½	—	—

Parasites.

I must just say a few words about the parasites which attack salmon. In addition to the gill-maggots, which I have already dealt with, there are two other beasts which attack the fish while they are in the river—leeches and the fresh-water louse. The former are not so common in the Wye, but there are plenty of the latter, and they very soon attach themselves to salmon after they enter the river. As will be seen from the photographs (Plate XV.), they are rather venomous looking animals, but I believe that they do not do very much harm to the fish. They are not present in all rivers, for I know that some of my Scottish fishing friends have never seen any, and they do not seem to have heard of them in the western rivers of Norway.

The most interesting of these pests are the sea-lice, which attack the salmon in the sea, and do not die immediately in fresh water. (Plate XIV., Figs. 3, 4 and 5.) The female is much larger than the male, as will be seen from the photographs. As a rule, the former has long white " tails " attached to it. These are the egg-strings, and they drop off very soon after the salmon enters the river, so that if one finds these on a salmon, one can be quite sure that the fish is quite fresh-run. The females are the next to go, and the males survive the longest. I formerly supposed that sea-lice would not survive in fresh water for more than a few days, but I have recently come across some facts which clearly indicate that under certain conditions they can remain attached to their host for certainly a week, and possibly a little longer—probably for not more than a fortnight. A good deal depends on the time of the year and on the temperature of the water.

PRACTICAL RESULTS.

I have, to the best of my ability, given you a description of the various classes of salmon which are to be found in the Wye, and have traced their life-history from the hatching of the egg up to the, in many cases, final effort to reproduce their species. You may say, "This is all very interesting, but what is the practical good of it all?" Well, my reply is, that I am a practical business man, and have not had a scientific training, and therefore I am not inclined to give up a great part of my leisure in investigating any subject, unless I can see some possibility of useful results. Naturally the catching of salmon is to me the main attraction, but let me also add, I take the deepest interest in the economic side of the question. One of my main hopes in life is to live long enough to see a very much larger quantity of salmon being produced in this country. As I said before, I am convinced that our salmon fisheries can be immensely improved, but this means legislation or some form of public control.

Now, it will be quite evident to anyone who thinks, that unless we have accurate knowledge of the real facts of the life-history of the fish, it is quite impossible to promote sound legislation. Most of our previous legislation was based on ignorance. I will give you a few examples. It was formerly supposed that the salmon parr belonged to a separate species, and did not grow into salmon. They actually invented a Latin name for them. We now know that anyone who kills a parr is destroying a potential salmon. It was also said that grilse did not spawn, and therefore we had better catch all we can. Netsmen who work in fresh water (which I think ought to be stopped, or at any rate controlled) will to-day tell you that spring-fish have not come to the river to spawn but will go back again to the sea. Therefore, again, we ought to catch all of them while we can. There are many other similar theories in existence, and it will be found, on examination, that most of them are merely excuses to try and justify over-netting and over-fishing.

Let me once again express my grateful thanks to Mr. Johnston for having provided us with the means of acquiring accurate knowledge of the real facts, and which will, I hope, result in proper measures being taken to bring prosperity to our salmon fisheries.

Divided Migration and Return.

There is one extraordinary fact which scale-examination has revealed, and that is the astonishing manner in which the results of one single spawning season are spread over a considerable number of years. This will be made clearer by the accompanying table showing the results of the 1913 spawning season in the Wye.

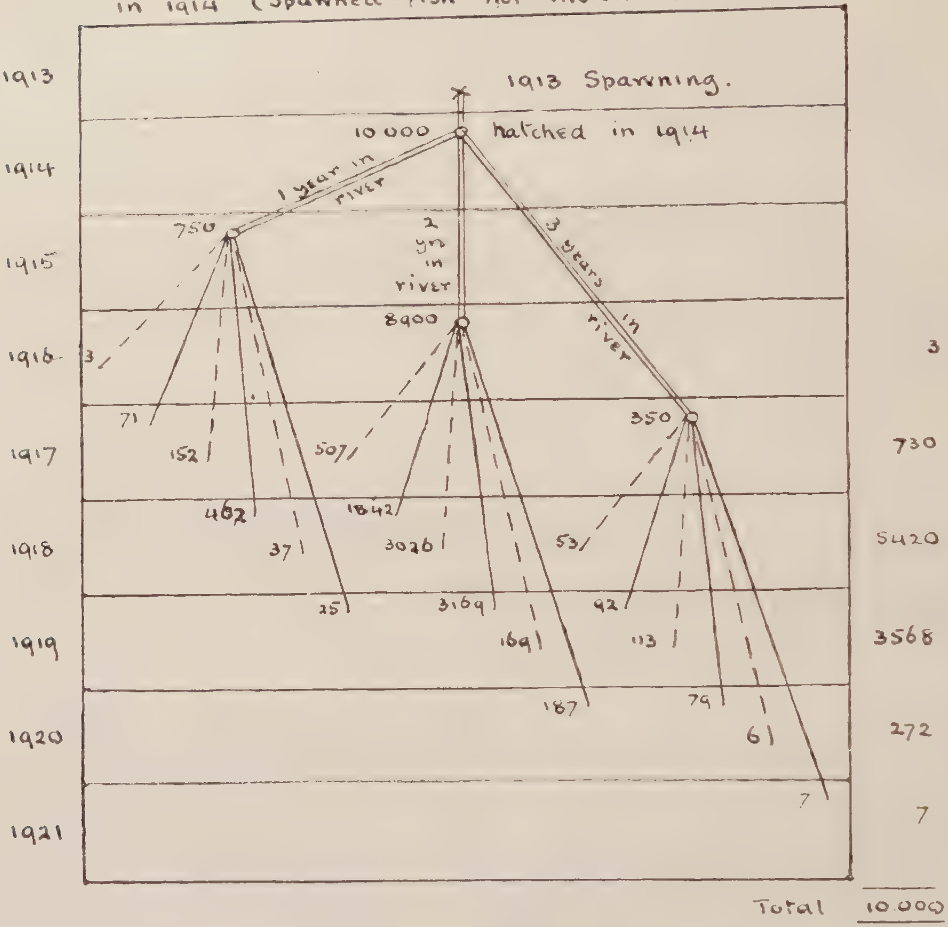
As will be seen from the table (p. 52), the ova hatched out in 1914, but there is a division straight away into three classes. Of the 10,000 parr which survived to return as mature salmon in subsequent years, 750 migrated as smolts in 1915 when only one year old. The largest number, namely, 8900, migrated on the completion of their second year in 1916, leaving 350 to go down to the sea in 1917 when they were three years old.

Further examination will show that each of these three classes is further divided into six sub-sections. Take the two-year-old smolts as an example: 507 returned as Grilse in 1917, and 1842 as Small Spring- and 3026 as Small Summer-fish in 1918. Then, in 1919, from this same migration of smolts, we have 3169 Large Spring- and 169 Large Summer-fish, leaving 187 to return in 1920 as Very Large Spring-fish.

The one-year and the three-year smolts are also sub-divided in the same manner, so that the 10,000 are split up into eighteen

TABLE II.

Divided migration and return of 10 000 fish hatched in 1914 (Spawned-fish not included).



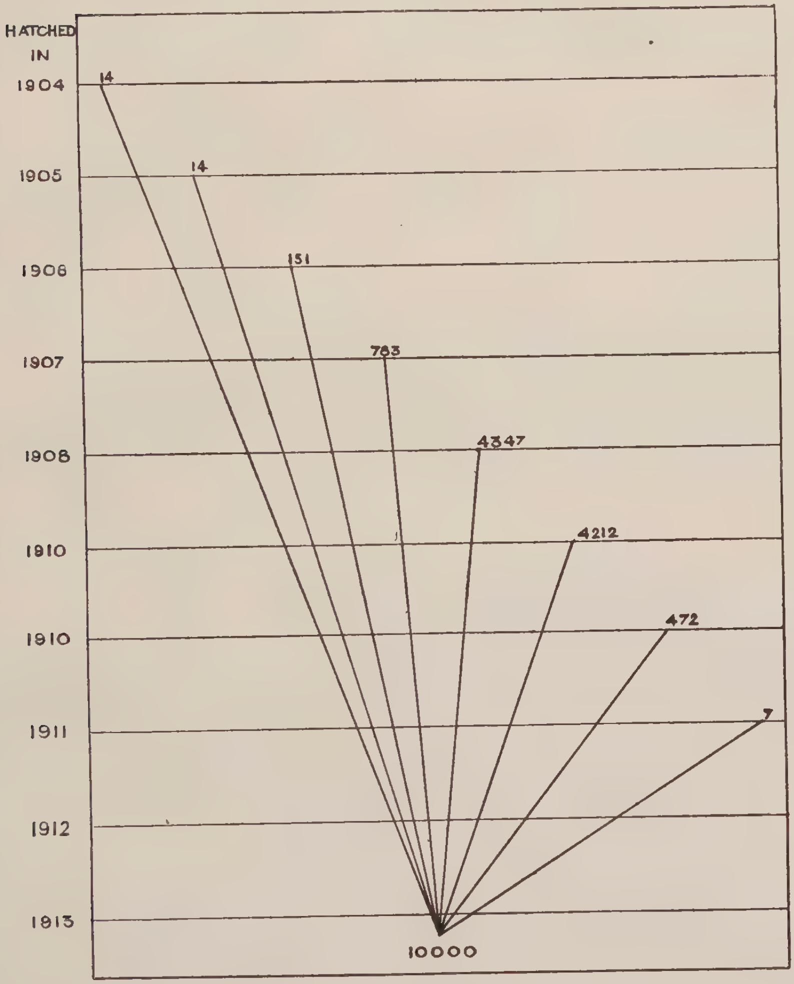
separate groups, with the final result that their return to the river is spread over six separate years, as follows :—

1916	1917	1918	1919	1920	1921	
3	730	5420	3568	272	7	= 10,000

Now these are not imaginary figures, but are based on actual statistics acquired by means of scale-examination.

TABLE III.

Divided migration and return of 10,000 fish caught in 1913, including spawned fish.



In the above figures I have taken no account of the fish which would have survived to spawn a second or third time. I have therefore worked out the figures in another way. The total catch in the Wye in 1913 was close on 10,000 salmon, namely, 3538 with rod and line and 6408 from the nets. In that year I received scales from 1382 fish. The accompanying table (see p. 53) has been drawn up on the assumption that these scales were representative of the whole catch.

This table shows that the 1913 catch depended on no less than eight separate spawning seasons, namely, from 1904 to 1911.

What applies to 1913 is applicable to other seasons, and what happens in the Wye will, with variations due to local conditions, happen in other rivers. The practical result is that the catch of salmon in every river in each season is a harvest dependant on the sowing, with, however, this difference from ordinary crops, that it is the result of the sowing of several years. It is, I think, another of these wonderful arrangements of Nature. She takes out a kind of insurance policy, which will make it certain, no matter what happens, that there will always be a stock left in the sea to perpetuate the species.

The Salmon Catch a Harvest.

The important point I wish to impress on you is the fact that the annual catch in every one of our rivers, no matter whether from rod-fishing or from netting, is a harvest, and like all harvests, depends on one main factor, whether the seed be sown. If the seed is not sown we cannot expect to reap. Any farmer who sowed no seed and expected to reap a crop of oats, or barley, or wheat, would be regarded as a fitting inmate for a lunatic asylum. I think in the management of our salmon fisheries we show a considerable amount of lunacy. The one vital factor is the sowing, and our salmon harvest every year depends on this one factor—the number of salmon which in each season are allowed to spawn unmolested. As I said before, if the proverbial messenger came down from Mars, he might well imagine that our main object was to prevent that seed being sown.

What We Now Know.

There are certain facts which we now know :—

1. Salmon can only breed in the rivers, for salt water is fatal to the eggs.
2. As a rule, the parr remain for two years in the river and then migrate to the sea as smolts.
3. They remain there for a period varying from one and a half to four years and then return, each one to its own river, to spawn.
4. The future harvest of each river depends on the number of salmon which are allowed to spawn in that river.
5. If a sufficient proportion of each class of salmon are not allowed to spawn in each season, the harvest will suffer in future years to a corresponding extent.
6. Nature, if we give her a fair chance, will do most of the work for us.

Therefore the question logically follows as to what we can do to develop our salmon fisheries. While the fish are in the sea we can do nothing, except to trust to Nature, and, as I think I have shown, she is quite capable of making suitable arrangements for the protection of the species. It is only when they approach the coast that salmon come under our control, and the whole future of our salmon fisheries depends on whether we exercise that control in a reasonable or in an unreasonable manner. This question of control applies to three important periods in the life of the salmon, namely :—

1. The parr-life in the river.
2. The smolt-migration to the sea.
3. The spawning-migration when they return to the coast and run up the rivers and spawn.

MANAGEMENT OF OUR RIVERS.

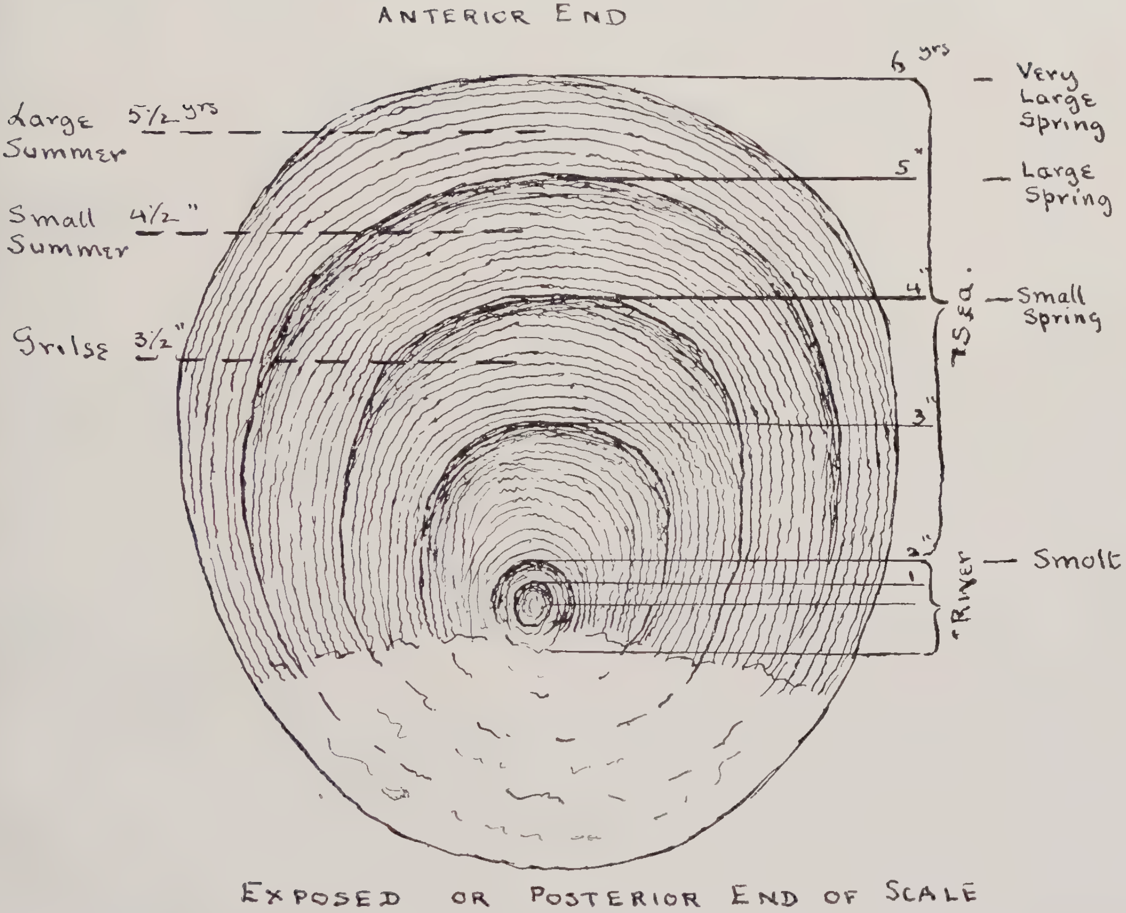
It therefore follows that future development depends on the way in which we manage our rivers and the approaches to them. I think it will be generally admitted that our present system leaves much to be desired. There is hardly a single river in this country which is producing the full harvest it is capable of, and this is entirely due to mismanagement. I don't say that all of us are possible candidates for the interior of lunatic asylums, but I feel sure that there is a great deal of truth in Carlyle's saying about " mostly fools."

The first step is to make up our minds that our present system is wrong. It is not too much to say that it is unpractical, non-effective, and wasteful to the last degree. What we have got to do is to regard everyone of our rivers as a national asset, which has got to be managed so as to produce the greatest possible amount of water-power, drinking-water, food, and recreation for the community, with, of course, due regard for all the interests concerned. Speaking to Scotchmen, I have no hesitation in saying that it would be to the advantage of your country, and also of the whole community, if your Fishery Board were to take a little more interest in the welfare of your salmon fisheries. I can also offer the same advice to some of the authorities on my side of the border.

PLATE I.

Sketch of Salmon scale.

PLATE I



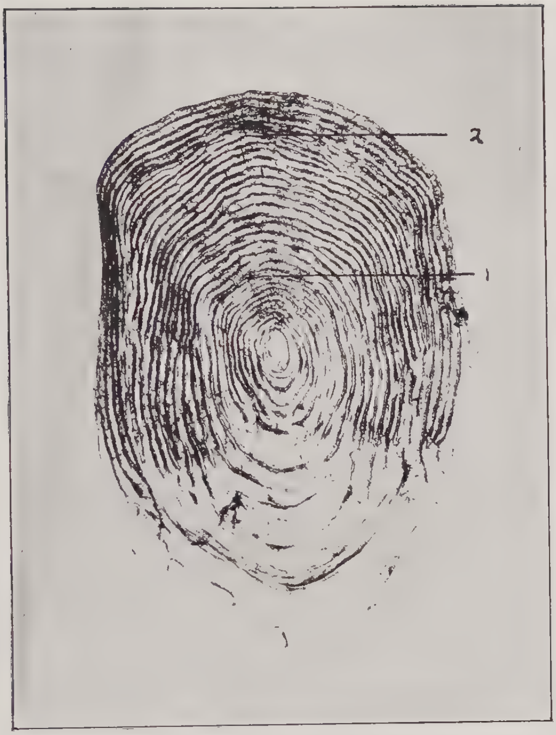
Sketch of Salmon Scale, showing 2 years Parr-life in river, and 4 Summer-zones and 4 Winter-bands formed in Sea

PLATE II.

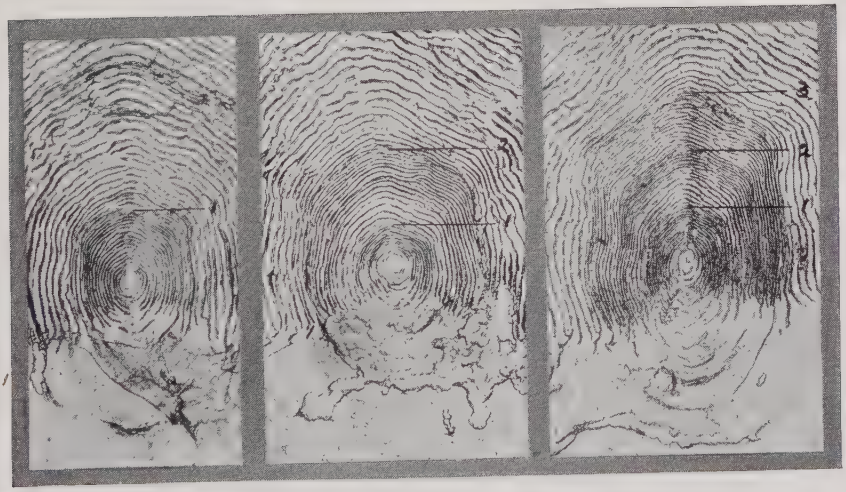
FIG. A. Scale from Wye smolt, April 17th, 1914 : $6\frac{3}{4}$ inches long, showing 2 years' river growth and a few new growth-rings formed during the third year. Magnification × 40.

,, B. Smolt-centres, showing 1, 2, and 3 years' river life. × 20.

PLATE II



A



B

PLATE III.

Scale from Wye grilse, July 14th, 1909: 5 lb. male, 24 inches long, showing 2 years in river and 1½ years in sea. 1. End of the first year in the river. 2. End of the second year in the river. 2-3. Summer growth in the sea, ending in a winter-band. From 3 outwards, the beginning of another summer-zone in the sea. × 16.

PLATE III

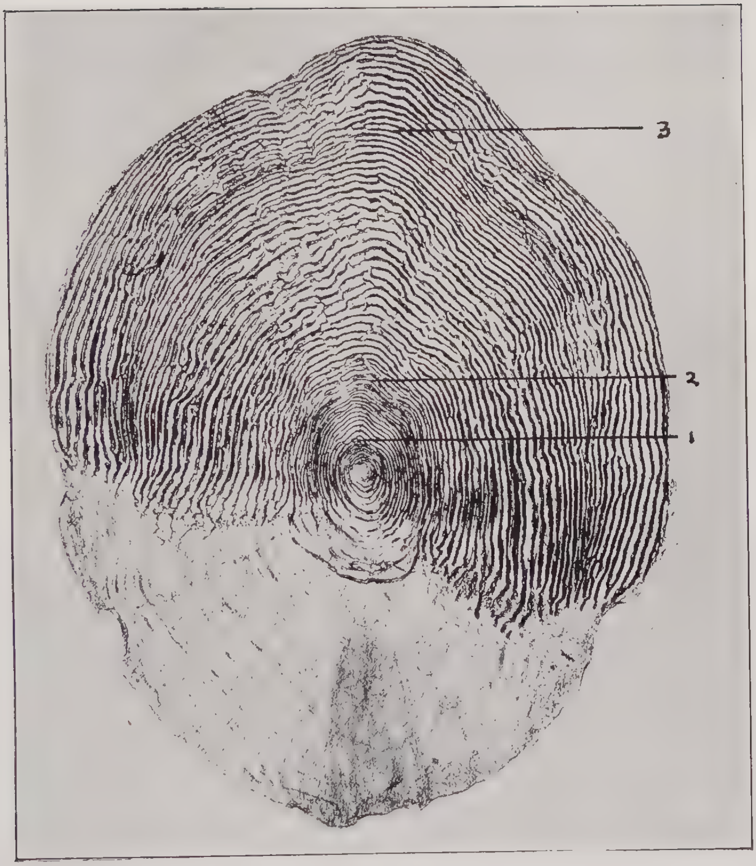


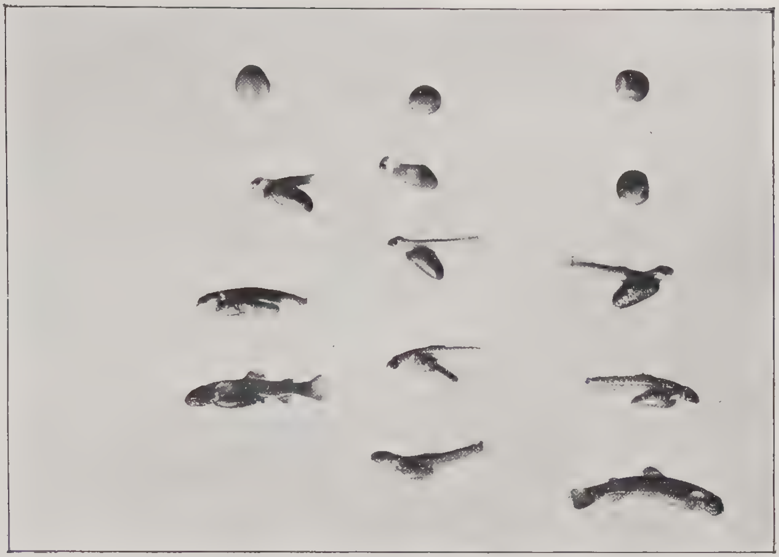
PLATE IV.

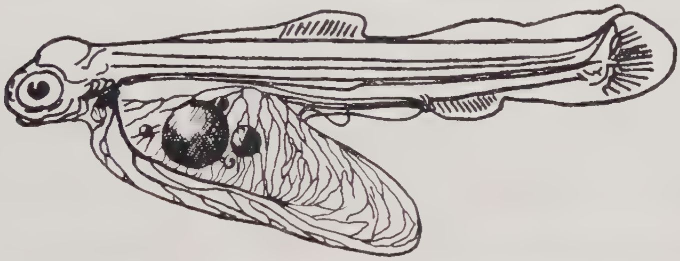
FIG. A. Ova and alevins, showing the gradual absorption of the yolk-sac. About two-thirds natural size.

„ B. Alevin. From a drawing by Professor Knut Dahl.

„ C. Wye salmon parr, 6 months and 18 months old.

PLATE IV





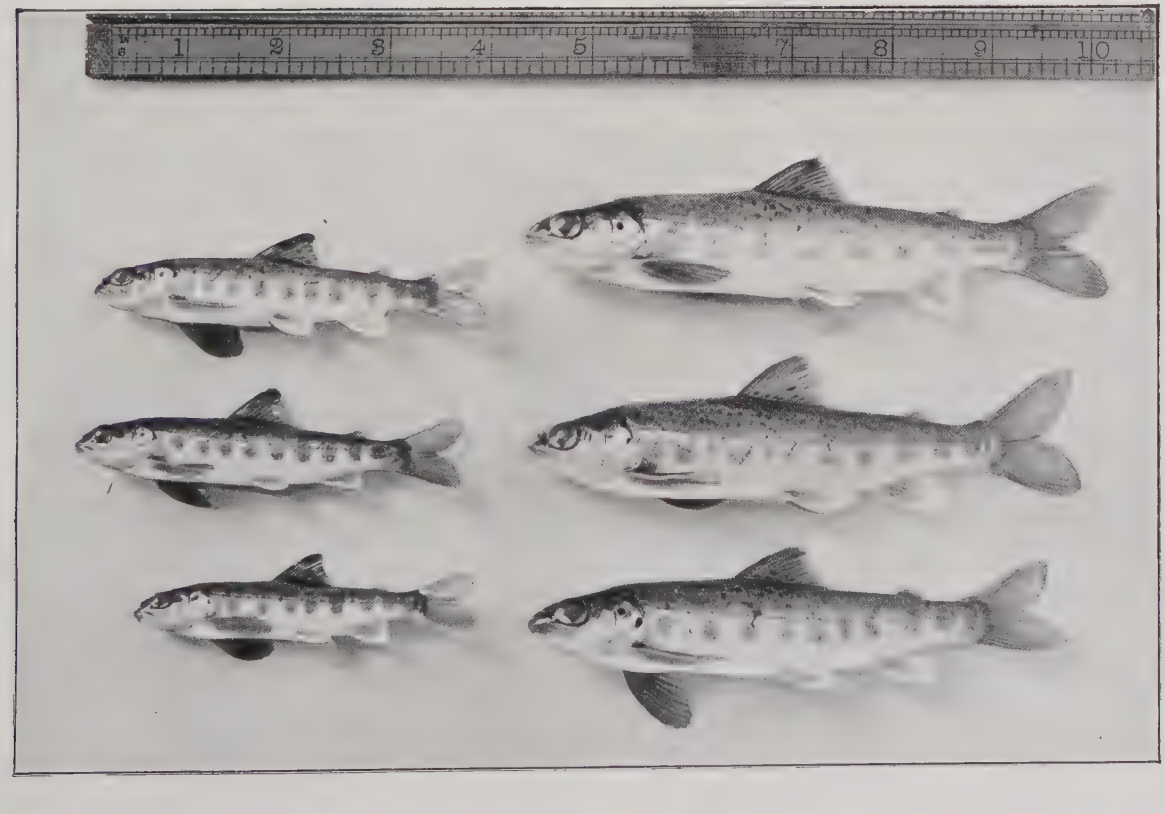


PLATE V.

A trout, a parr, and three smolts. The scales have been removed from the two smolts at the bottom of the photograph in order to show the parr colouring on the true skin, which lies underneath the scales.

PLATE V

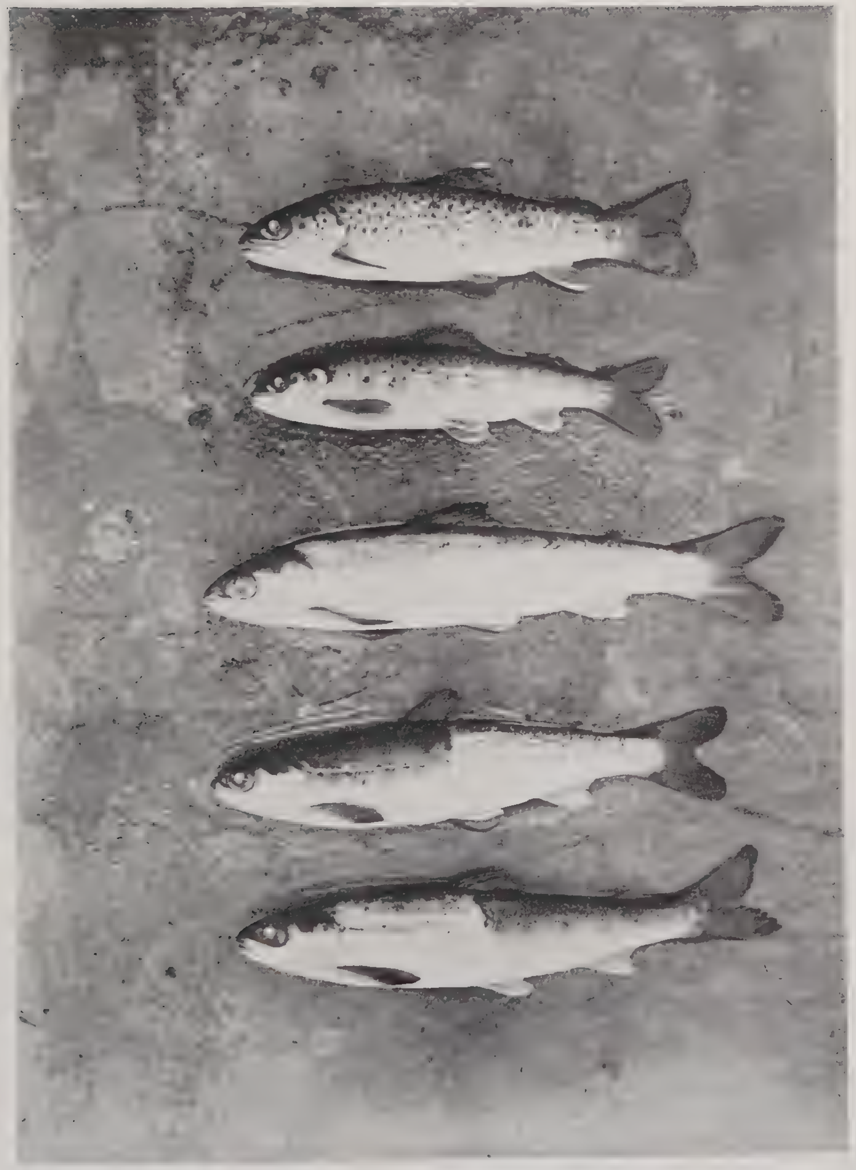
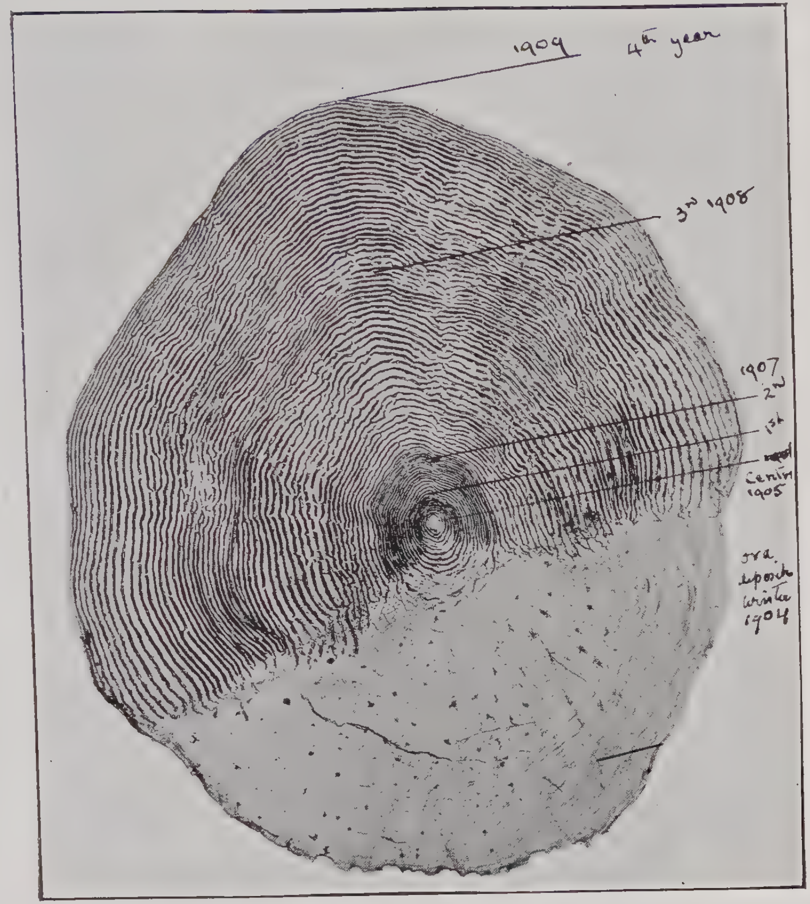


PLATE VI.

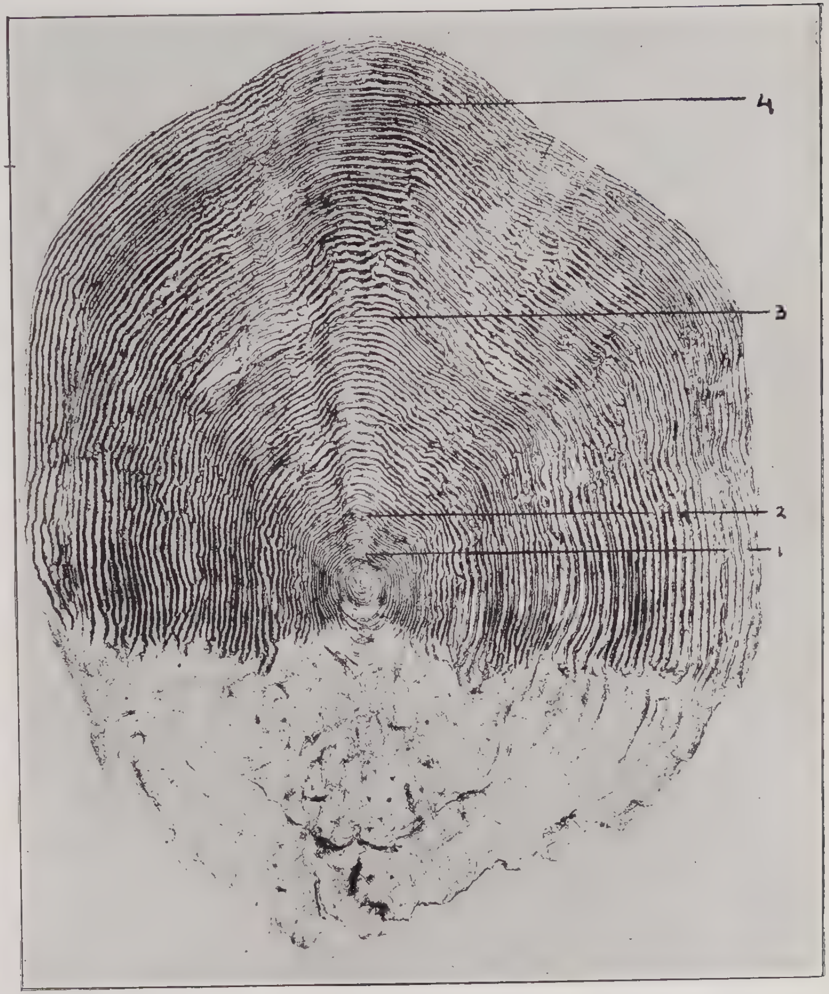
FIG. A. Scale from small spring-fish, April 19th, 1909: 9½ lb. female, 29 inches long, 2 years' river and 2 years' sea life. × 17.

B. Scale from small summer-fish, July 4th, 1919: 15 lb. female, 32½ inches long, 2 years' river and 2½ years' sea life. × 16.

PLATE VI


1909
4th year
3rd 1908
1907
2nd
1st
Centre
1905
3rd.
epoch
winter
1904

A


4
3
2
1

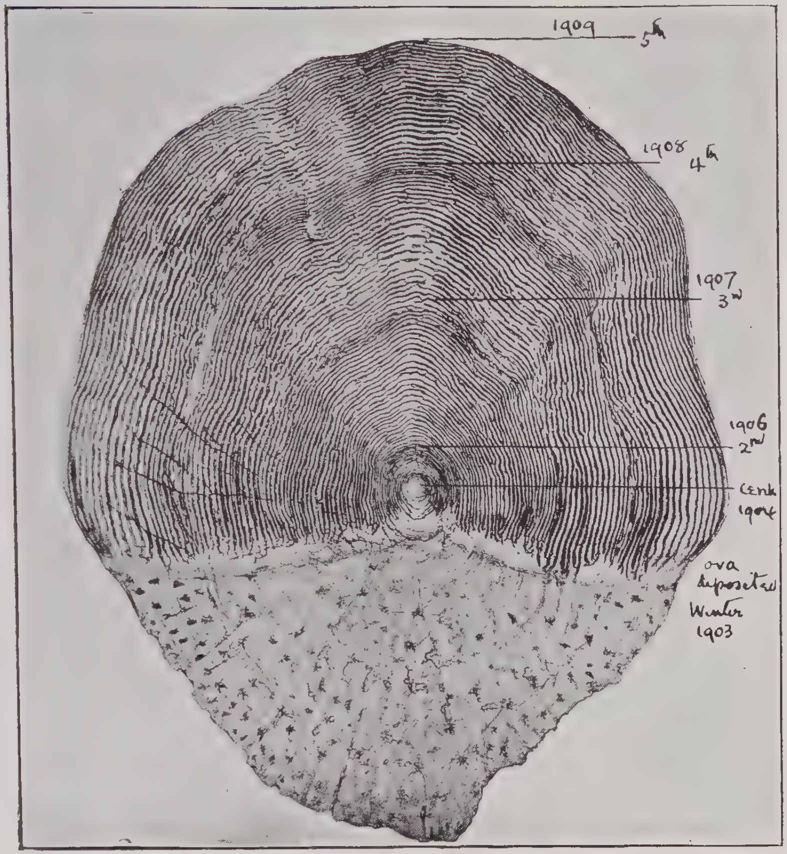
B

PLATE VII.

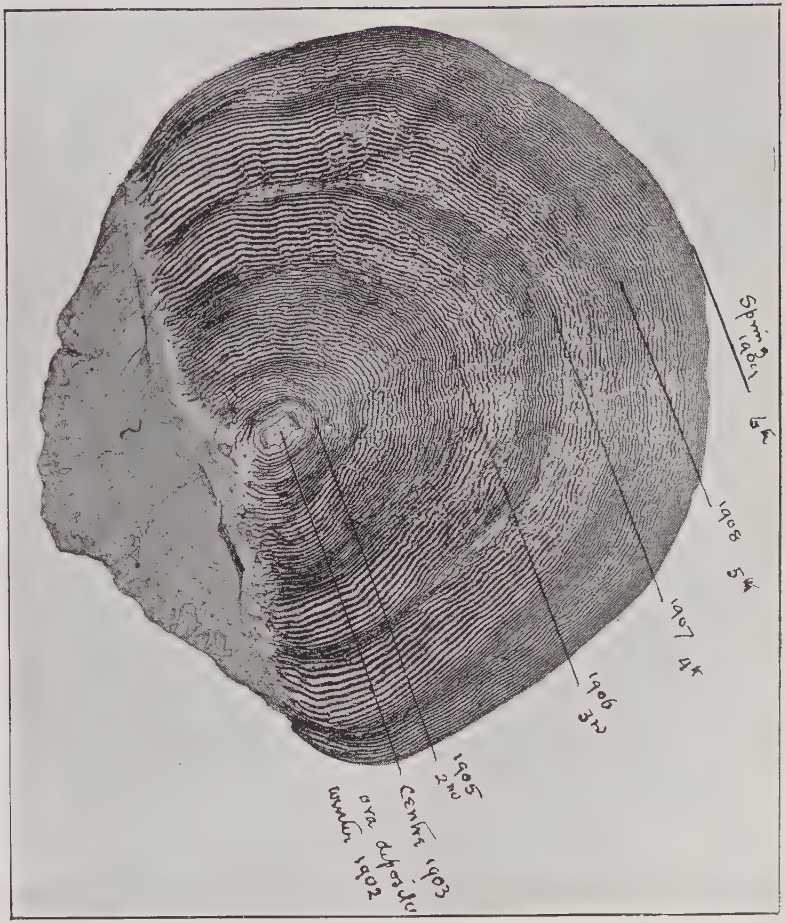
Fig. A. Scale from large spring-fish, April 7th, 1909: 22 lb. male, 38½ inches long, 2 years' river and 3 years' sea life. × 15.

" B. Scale from very large spring-fish, May 4th, 1909: 44 lb. male, 49 inches long, 2 (?) years' river and 4 years' sea life × 12.

PLATE VII


1909 5th
1908 4th
1907 3rd
1906 2nd
Centre 1904
ova deposited Winter 1903

A


Spring 1909 6th
1908 5th
1907 4th
1906 3rd
1905 2nd
Centre 1903
ova deposited winter 1902

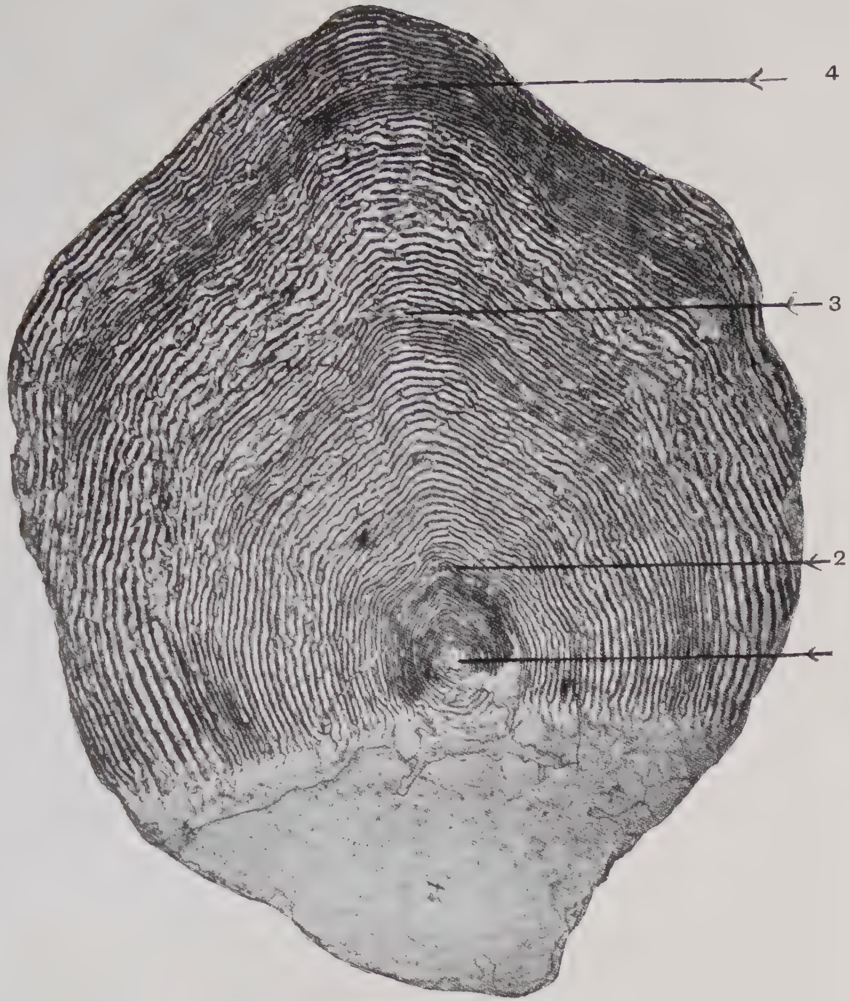
B

PLATE VIII.

FIG. A. Scale of small summer-fish, September 5th, 1908: 15½ lb. female, 36 inches long, 2 years' river and 2½ years' sea life. Showing the commencement of the "wearing" of the scales. × 16.

,, B. Scale of small summer-fish, September 5th, 1908: 14 lb. male, 35½ inches long, 2 years' river and 2½ years' sea life. Scale much "worn." × 16.

PLATE VIII



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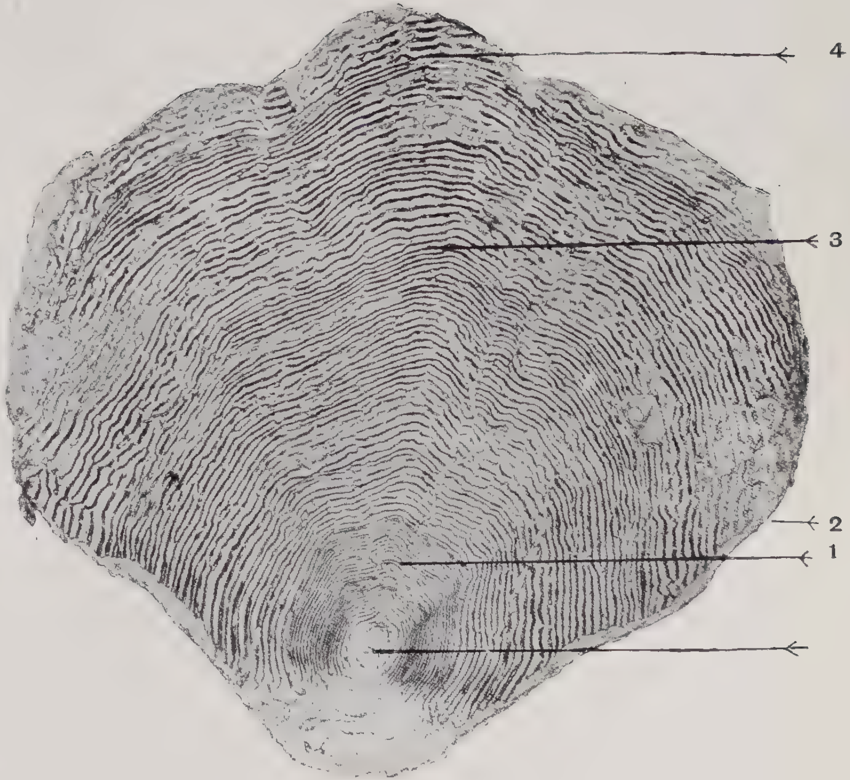


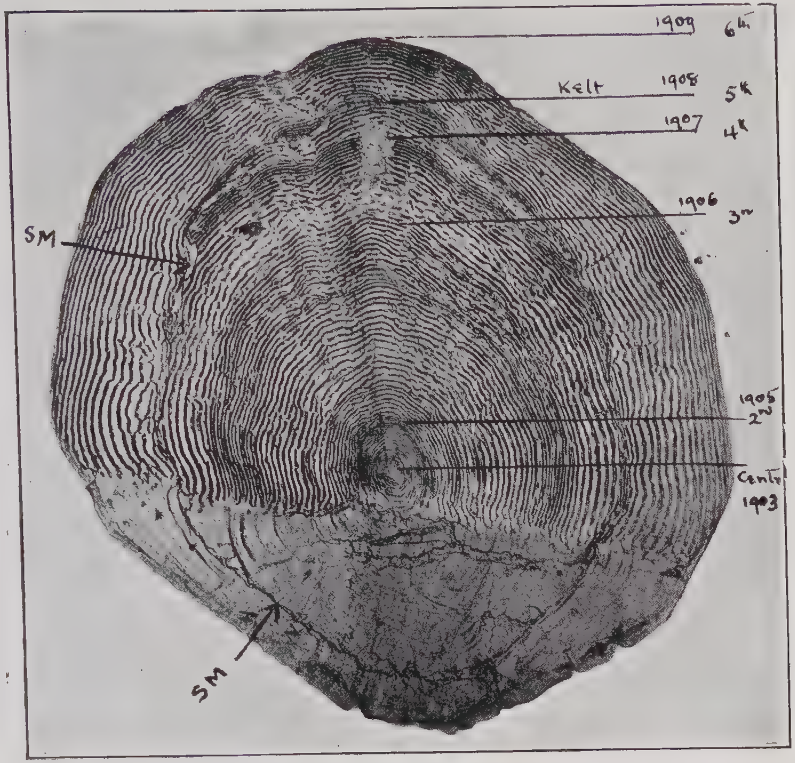
B

PLATE IX.

FIG. A. Scale of salmon with one spawning-mark, April 12th, 1909: 26 lb. female, 40½ inches long. × 12. This fish spent a full year in salt water after returning to the sea as a kelt early in 1908.

,, B. Scale of a Norwegian salmon with two spawning-marks, Christiansand, May 21st, 1909: 34 lb. female, 43 inches long. × 12.

PLATE IX


1909 6th
Kelt 1908 5th
1907 4th
1906 3rd
1905 2nd
Centre 1903
SM
SM

A

B

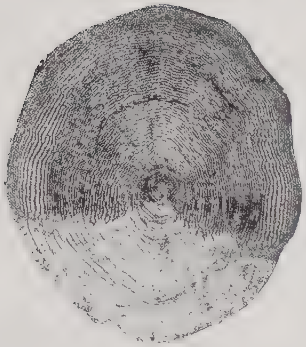
PLATE X.

This plate illustrates the gradual "wearing" of the scales prior to spawning. × 7.

1. May 12th, 1913: Wye nets, 11 lb. female, 30¾ inches. No sign of wearing of scale.
2. June 10th, 1913: Wye nets, 15 lb. male, 32½ inches. The posterior or exposed portion of the scale shows slight signs of wearing.
3. July 29th, 1913: Wye nets, 11 lb. female, 31 inches. The posterior portion and also the sides of the scale are slightly worn.
4. August 6th, 1913: Wye nets, 11 lb. male, 32¾ inches. The posterior portion and also both sides of the scale are considerably worn.
5. September 19th, 1913: Wye nets, 13 lb. female, 34 inches. A considerable part of the posterior portion of the scale has disappeared, and disintegration of the surface has commenced.
6. October 4th, 1913: Caught in the river, 12¾ lb. male, 33½ inches. This fish was very red and well advanced towards spawning. The scale is excessively worn, and the posterior portion and part of the sides have almost disappeared, and the surface is much disintegrated—a typical scale of a cock-fish just before spawning.

PLATE X

1



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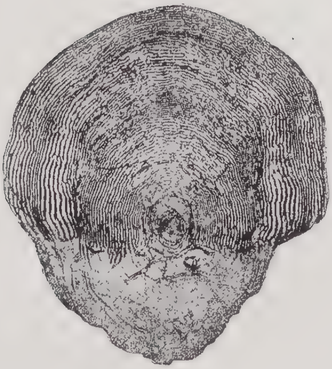

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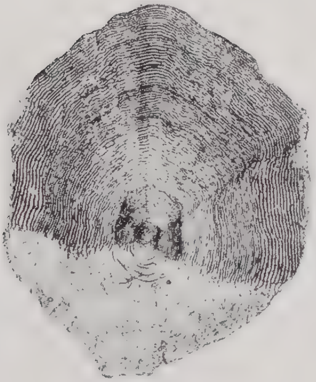

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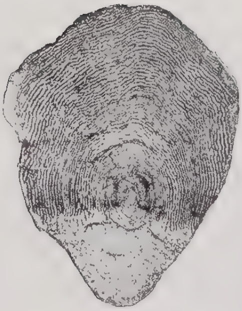

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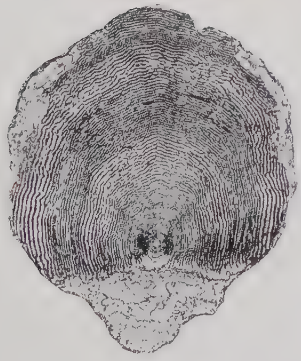

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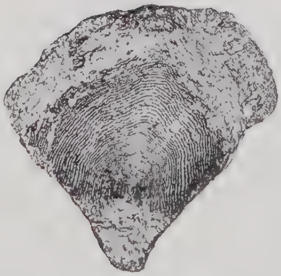


PLATE XI.

This plate illustrates the scar or "spawning-mark" resulting from the "wearing" and disintegration of the scales. × 7.

7. February 17th, 1913: 24 lb. female, 41 inches. This fish spawned at the end of 1911. Spawning-mark only slightly shown.

8. February 15th, 1913: 29 lb. female, 41½ inches. Spawning-mark more clearly shown. Spawned at the end of 1911.

9. March 10th, 1913: 25½ lb. female, 40 inches. Spawned at the end of 1911. Spawning-mark very clearly shown, as some of the surface of the scale had disappeared before the fish returned to the sea as a kelt in the spring of 1912.

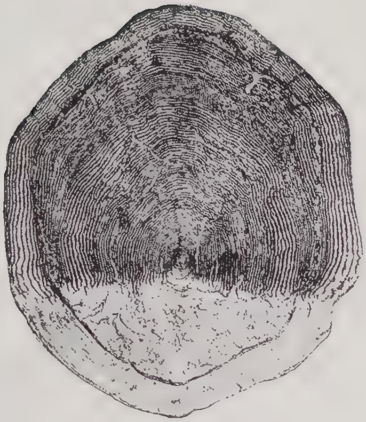
10. October 12th, 1912: 17 lb. female, 39 inches. This fish spawned at the end of 1911, and returned to the sea as a kelt early in 1912; but instead of remaining in the sea through the following winter, as was the case with Nos. 7, 8, and 9, it returned to the river as an autumn-fish, adopting what Mr. Calderwood has termed the "short-period," as opposed to the "long-period" of migration. The surface of the scale was much disintegrated, and a new centre of ring formation has commenced on the anterior portion of the scale just to the left of the centre.

11. April 15th, 1912: 27½ lb. female, 43 inches. Two spawning-marks, which are only slightly shown on the anterior portion of the scale.

12. February 20th, 1913: 24¾ lb. female, 40½ inches. Two spawning-marks are clearly shown round the greater part of the scale.

PLATE XI

7



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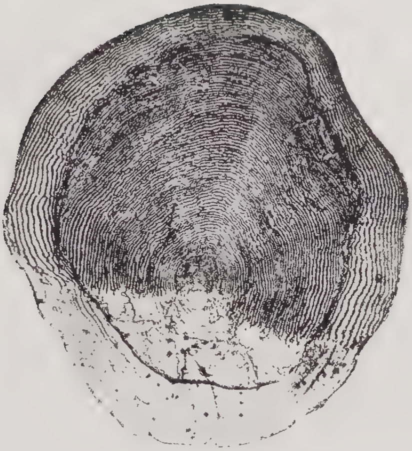

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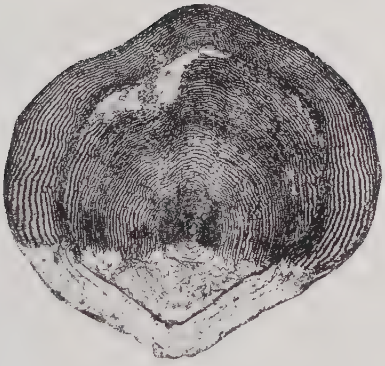

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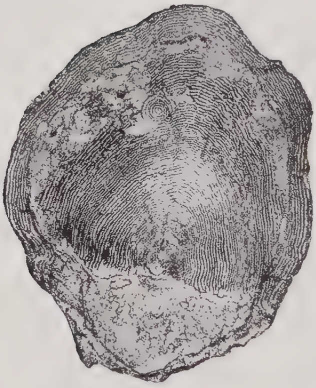

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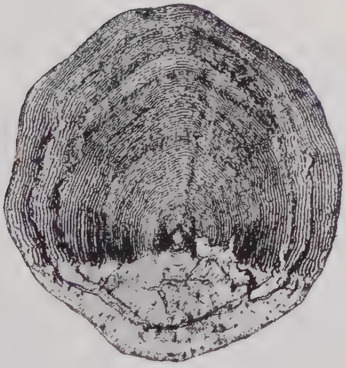

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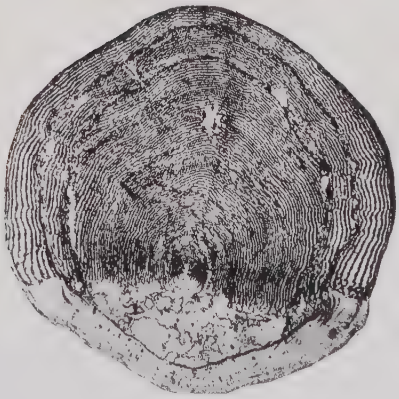


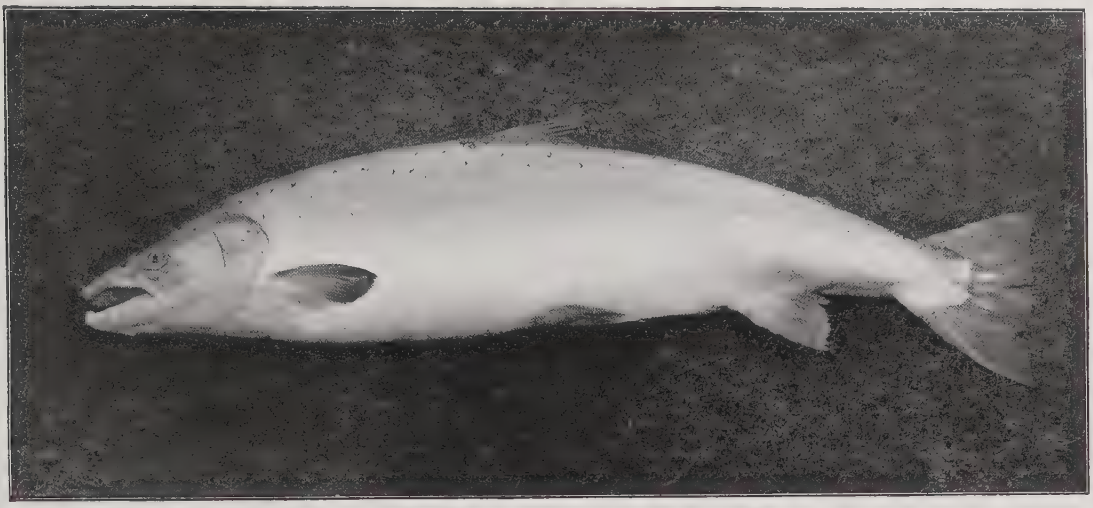
PLATE XII.

FIG. A, 36 lb. maiden male spring-fish. Note that there are very few spots on the gill-covers and not many on the body, and none below the lateral line.

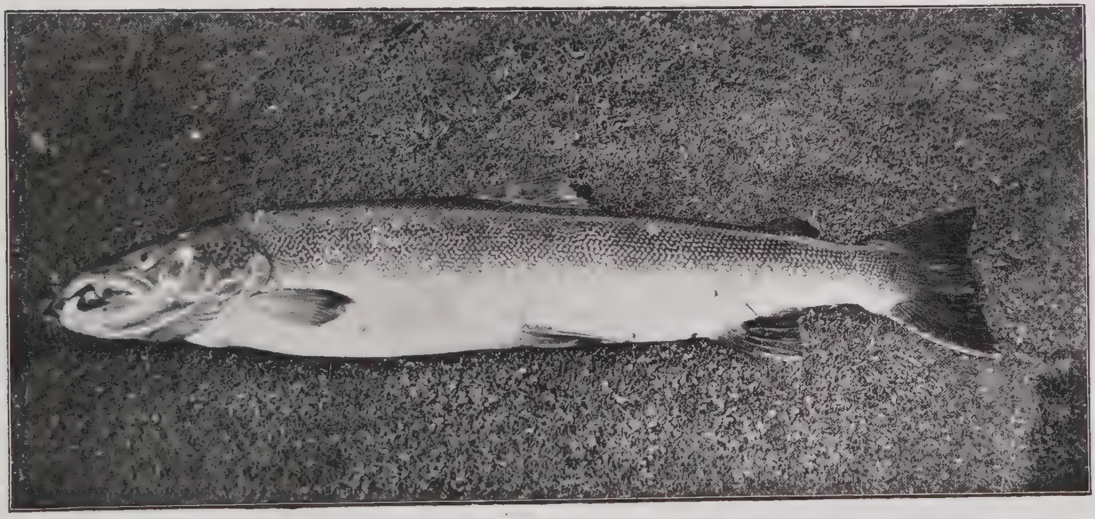
,, B. 30 lb. male fish in full "spawning-livery" in the autumn just before spawning. Note the development of the "beak" on the lower jaw.

,, C. 26 lb. female spring-fish which has spawned. Note the numerous spots on the gill-covers, and also the spots and "speckles" on the body both above and below the lateral line. These are a sure sign that the fish has spawned before.

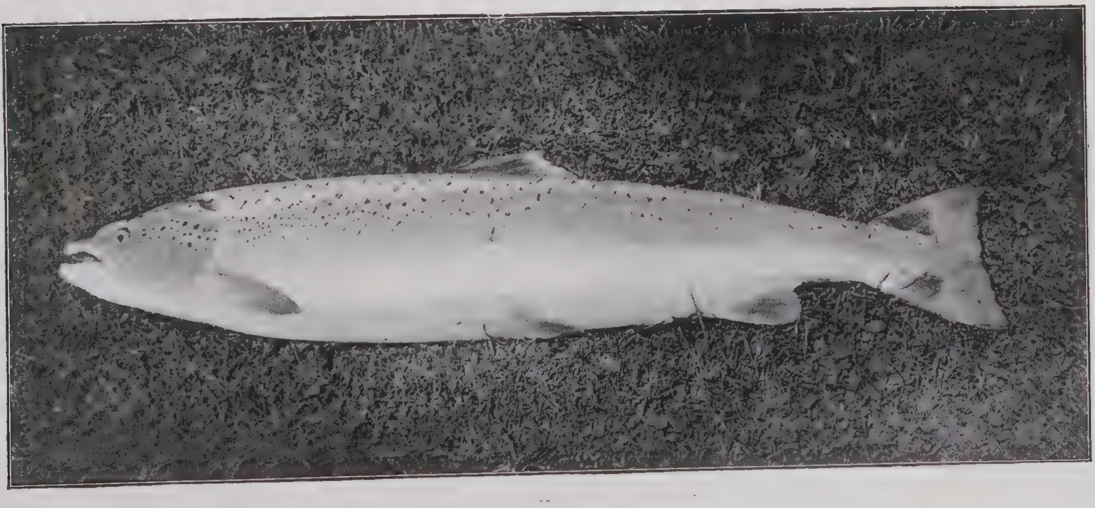
PLATE XII



A



B



C

[illegible] is mostly [illegible] and [illegible] hatched have the paws of [illegible]. Note the difference in the shape of the heads in the two sexes. The head of the female is a little shorter and more pointed. The head of the male is longer and [illegible]

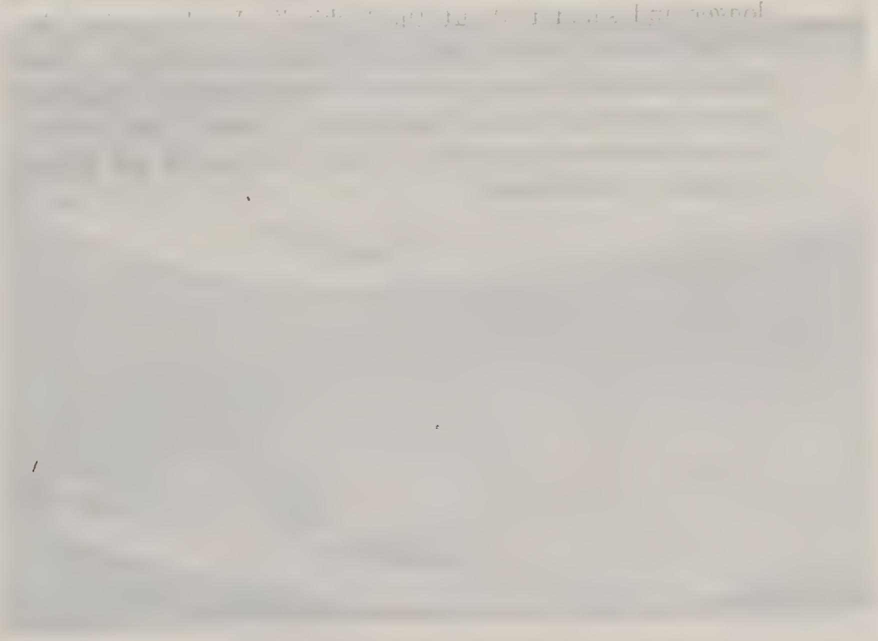


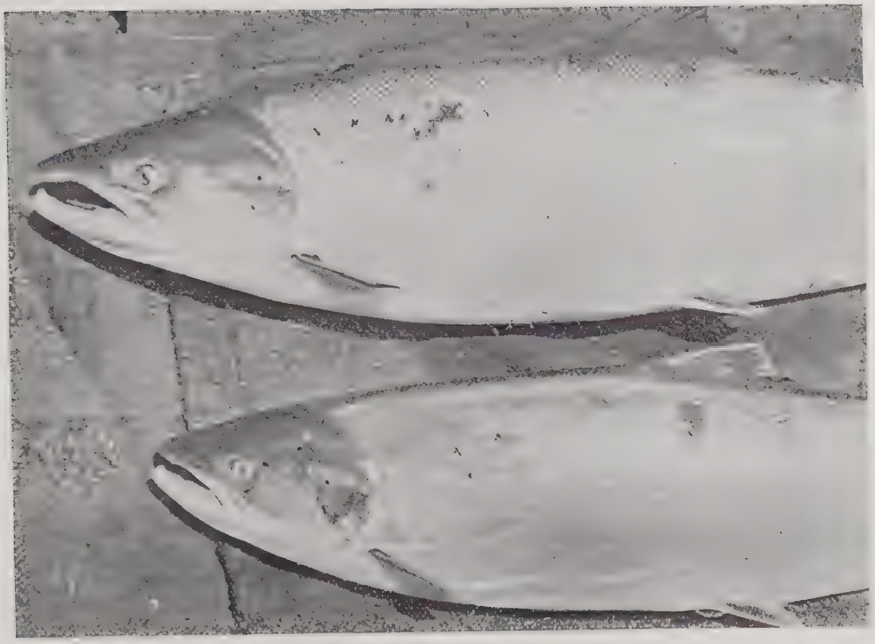
PLATE XIII.

FIG. A. Large spring-fish, cock, 30¼ lb. ; hen, 22¾ lb.

,, B. Small spring-fish, hen, 10 lb. ; cock, 12½ lb.

Note the small number of spots on the gill-covers, and that there are very few on the body below the lateral line. This is usually the case with *maiden* fish which have not spawned before. Note also the difference in the shape of the heads in the two sexes. The head of the female is a little shorter and more pointed. The head of the male is longer and squarer about the "chin." In the spring the "beak" on the lower jaw is only slightly developed. The upper jaw ends in a sort of snout, which gradually lengthens as the spawning season approaches. There is also a sort of snarl or curve on the lower side of the upper jaw which is absent in the female.

PLATE XIII



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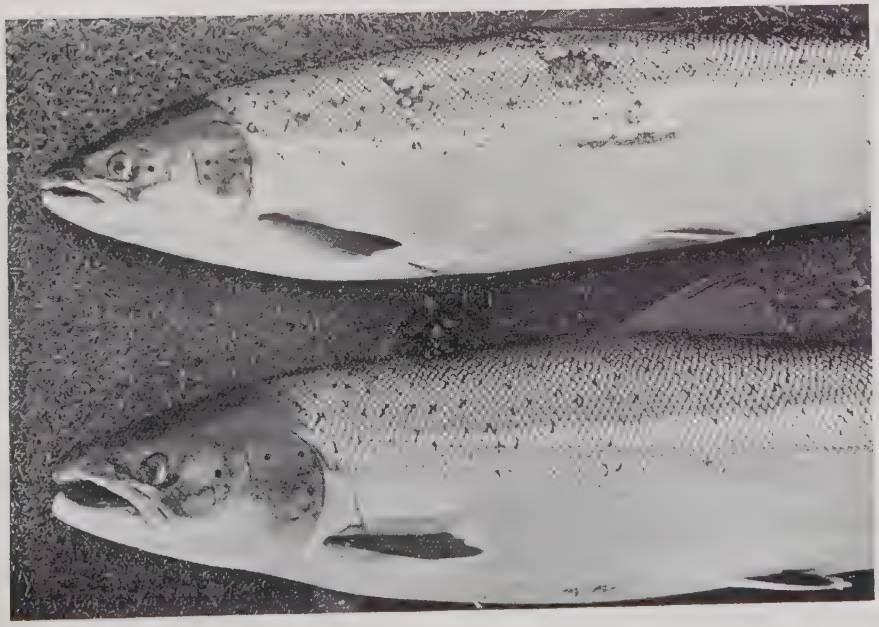


B

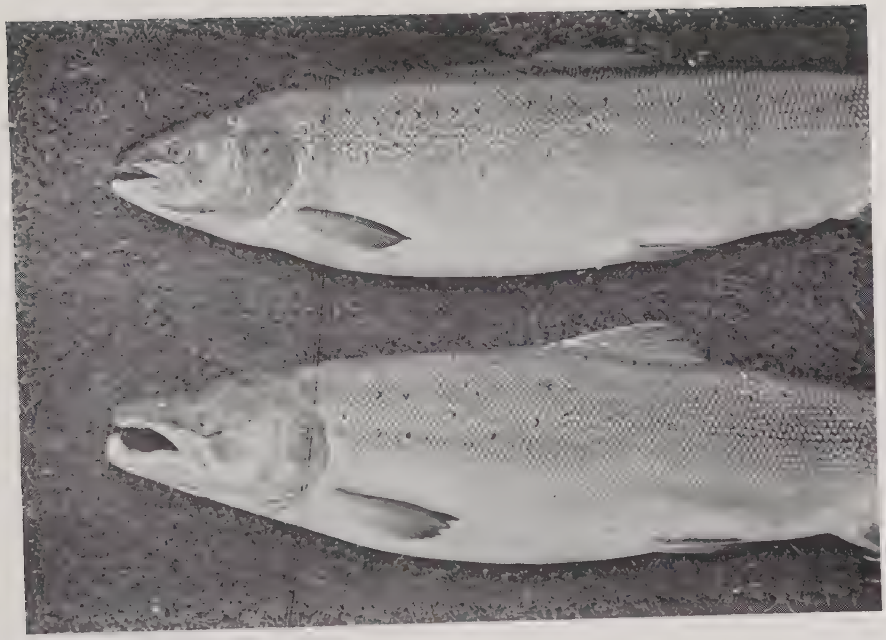
PLATE XIV.

FIG. A. Autumn-fish—hen, 12¼ lb.; cock, 10¾ lb.

Note that these are much darker in colour than spring-fish. The "beak" on the lower jaw of the cock-fish is nearly fully developed.

B. 12½ lb. hen-fish with its ova nearly fully developed. This fish was caught in September, and would have spawned within a month.

PLATE XIV



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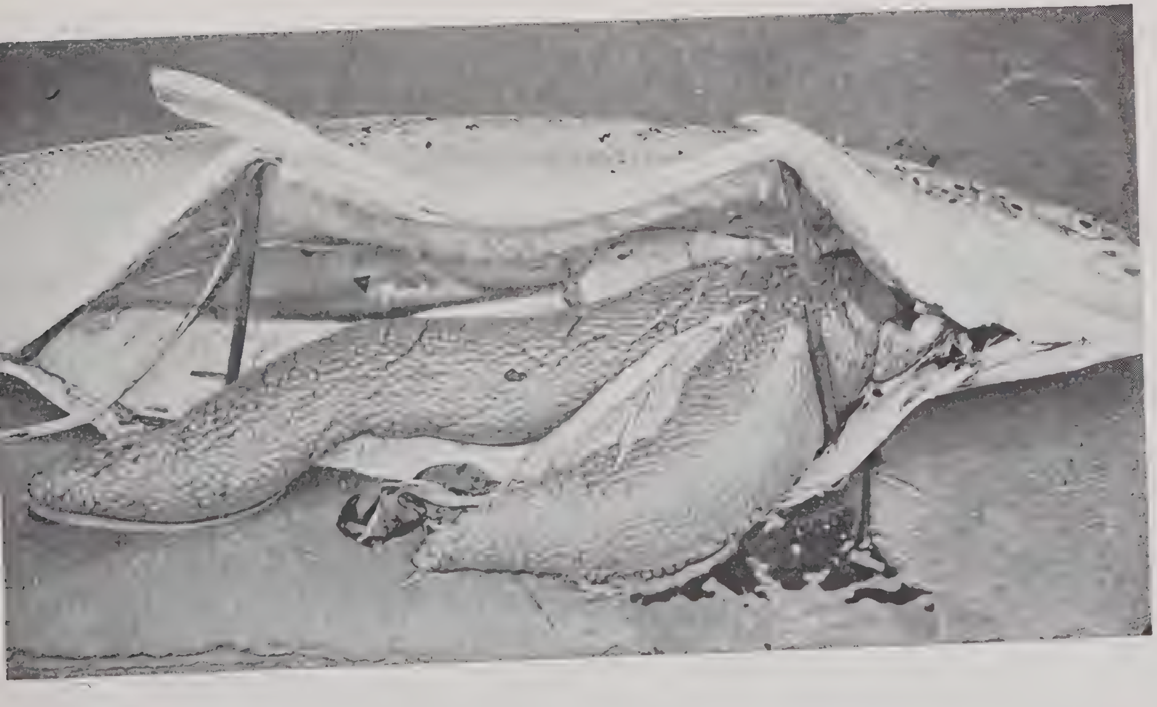


B

PLATE XV.

Crustacean parasites of salmon.

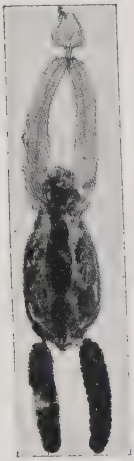
1. Gill-maggot, female, × 6, with attaching appendages in front and two egg-sacs behind. Its technical name is *Lernæopoda salmonea ;* it is one of the Copepods. The body of the female is about a quarter of an inch in length. The males are dwarfs.

2. Freshwater-louse (*Argulus foliaceus*), × 4. Ventral surface. It has a flat body and four pairs of swimming appendages. It fixes itself by a sucking proboscis with stilets, a poisonous spine, and two suctorial discs. The last are seen on the photograph behind the two black eyes which are shining through from the dorsal side. They can loosen their grip and swim about for a while, and change from one fish to another. They do not carry egg-sacs like the gill-maggots, but lay their eggs in strips on stones and plants. They sometimes make serious holes in the skin of the salmon. This is also a Copepod. It is about one-fifth of an inch in length.

3. Sea-louse (*Lepeophtheirus stromii*), × 4, showing the full length of the egg-strings, twice as long as the body. The length of the body is about three-fifths of an inch. This is another Copepod, feeding on blood.

4. Sea-louse, male ; 5, the female ; both × 8. These photographs show the striking difference in size between the sexes.

PLATE XV



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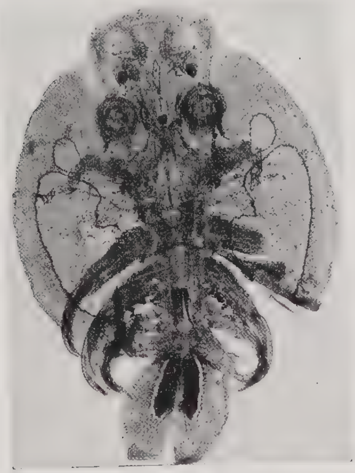

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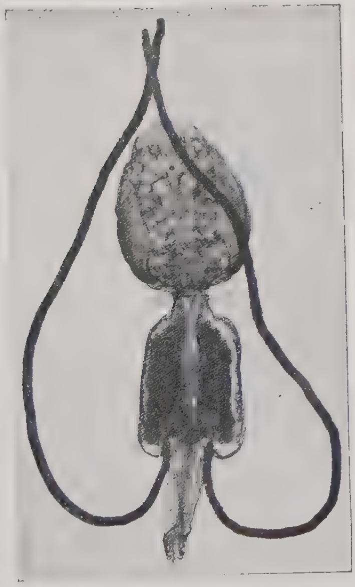

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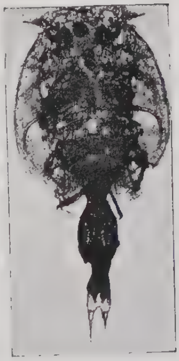

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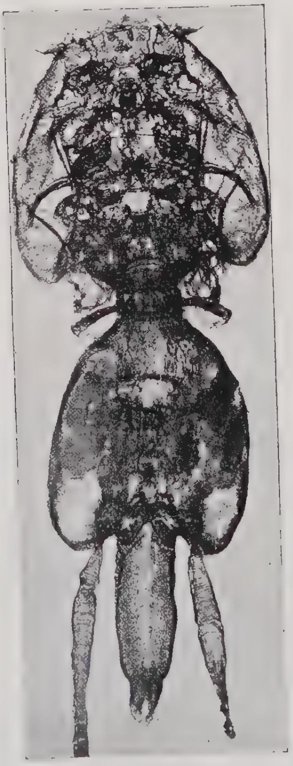

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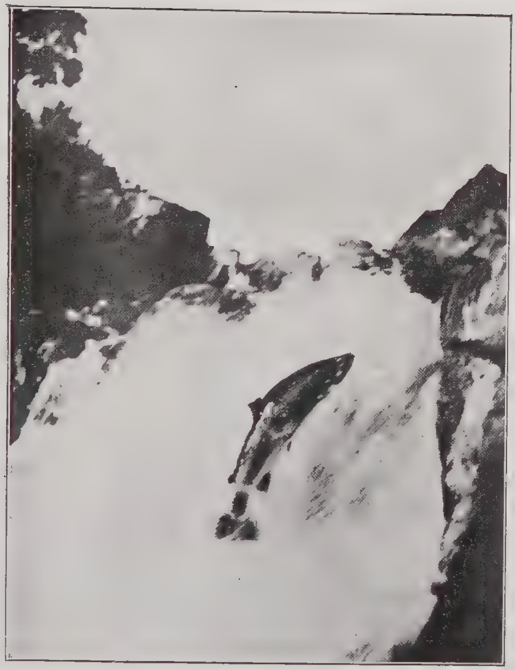
PLATE XVI.

The new salmon "pool-pass" on the Fitz Weir on the Cumberland Derwent.

PLATE XVI

PLATE XVII



FALLS OF TUMMEL *Photo. H. W. Johnston*

SALMON LEAPING AT THE FALLS OF TUMMEL

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